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HOW FAR CAN MAN CONTROL HIS CLIMATE?

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FROM the beginning of human history the artificial control of weather and of climate has been of interest to man. It matters not how "perfect" a climate may be; or where man lives; or what specific use he wishes to make of the atmospheric conditions that surround him, there is always something that is unsatisfactory or injurious or disagreeable in what nature provides. It is too hot or too cold. There is too much or too little rainfall. Frost kills crops. Winds are too strong and injure what man has planted. Lightning wrecks buildings and sets them on fire. Hail beats down and may destroy fields of wheat or orchards of fruit. Long-continued cool and cloudy weather retards the growth of crops. Droughts, if they last long enough at a critical time, may cause irreparable damage.

Many absurdly fantastic notions concerning man's control over weather have been, and are still, current. Thus, a western newspaper has lately suggested, it is to be hoped jocosely, that the completion of the new tunnel through the Cascade Mountains on the Great Northern Railway may alter the climate by making it possible for cold air from the continental interior to flow westward through the tunnel. Preposterous as this idea is, it is hardly as hopelessly fantastic as was the view, seriously advanced a good many decades ago, that deforestation on the northern Pacific slope of the United States would change the climate of Europe. The building of railroads and the construction of telegraph lines in the western United States were believed by many people to have brought about a change in the climate of that region, and similar views were held in England when the first railroads were built there. The Mexicans in California are reported to have blamed the Americans for bringing thunderstorms as a result of new railroad construction. Very recently, the world-wide use of the radio has been thought, both in the United States and elsewhere, to have caused unseasonable weather. Professor C. F. Talman, of the U. S. Weather Bureau, has reported that during a summer cold spell in Poland two years ago, the peasants tore down the radio antennae in order to bring better weather. The wide-spread prevalence of this view of an influence of radio on weather was illustrated during the writer's visit in Shanghai last April. While there, he was reported in an interview in a local newspaper as believing that the severe winter over much of Europe was due to the influence of radio. It is hardly necessary to say that he made no such statement. The "interview" was purely a product of the reporter's imagination. Most unfortunately, this so-called interview was cabled to the American newspapers, and was quoted in some of them.

There is always a struggle of man against nature; always the effort to improve what nature has provided. Among the well-known attempts to control cer-

tain features of the weather are the protection of fruit and other delicate crops against frost; the many and varied attempts to make artificial rain, and the method of supposedly blowing a waterspout to pieces by shooting at it. None of these efforts, it should be observed, is directed at a complete control of all the weather elements. All of them concern individual phenomena only. Mark Twain was hardly correct when he wrote his often-quoted statement, "Everybody talks about the weather but nobody does anything about it." For century after century man has been trying to do something about it. But he is dealing with an immense atmosphere, unconfined, free to move—a physical laboratory in which experiments on an enormous scale are constantly being performed. There can be no hope, and no possibility, of exercising any control over this vast atmosphere as a whole, or even over any considerable part of it. The most, and the best, that man can ever hope to do is to deal with a very small part of it, over a very limited space at best. The fundamental processes of nature, in her great atmospheric laboratory, are concerned with many cubic miles of air. As Sir Napier Shaw has well expressed it, "We are lords of every specimen of air which we can bottle up or imprison in our laboratories. . . . In the open air we are practically powerless."

It is convenient and logical to consider man's attempts to deal with his weather and climate under three heads, or stages. These are, first, protection; second, prevention, and third, production. The first stage is perfectly passive. No attempt is made to change the normal order of nature. Man simply seeks to protect himself or his crops against what comes. The second stage is more active. In this it is sought to prevent conditions from occurring which are undesirable or injurious. The third stage is the most active and aggressive of the three. In this man definitely and seriously tries to produce something which is not otherwise present. He plans a campaign to bring about a result. He attempts to create a weather condition which nature does not herself, in her ordinary normal régime, produce.

In the first stage, the passive one, there is neither prevention nor production, but only protection. Here man accepts things as they are. He merely tries to shield himself against them. In this group of illustrations we have man's many methods of providing himself with shelter, ranging from the most primitive, such as the rock caves of early man, or the simple bamboo and palm-leaf huts of the tropics, to the most elaborate modern houses and other buildings, heated in winter in cold climates and without doubt more and more in the future to be artificially cooled during the heat of summer. An immense amount of time and of inventive skill has been expended in making this protection more and more adequate.

Tropical cyclones are among the most dangerous phenomena with which man has to contend. They devastate large areas, destroy crops, wreck buildings and often cause great loss of life. With an increasing population in the districts visited by these storms, and with the growth of cities and of industrial plants there, better methods of building are becoming more and more necessary. It is clear that man can do a great deal towards promoting the safety of human life in, and lessening the damage wrought by, tropical storms. Building regulations in the regions visited by hurricanes and typhoons should certainly take cognizance of these facts. Buildings can be constructed of heavier materials, such as reinforced concrete; roofs can be "tied on" more firmly; the foundations can be made more secure, and the structure be more firmly united with the foundation. Locations should be selected beyond the reach of the storm waves which cause most of the fatalities.

Cities on the coast can be protected by sea walls and by breakwaters, to lessen the dangers of floods resulting from the inrush of ocean waters. Inland settlements can be protected against the fresh-water inundations which so often follow the torrential rains.

In the case of tornadoes, the most violent disturbances in the atmosphere, tornado cellars provide adequate protection to life. Recent studies have shown that solid steel and concrete construction will resist the violence of ordinary tornado winds better than structures of brick or wood, although it is practically certain that no building which is exposed to the greatest fury of the winds or which passes through the center of a fully developed tornado will stand up, at any rate without very serious damage.

Protection against lightning is another aspect of this phase. We have advanced very far beyond the stage of fifty or more years ago, when the "lightning-rod man" traveled about the country, installing the old-fashioned tall rods on farmhouses and barns. The modern methods of lightning protection have been very carefully worked out. The general idea is to enclose the building in a wide-meshed metal "cage," so to speak. The ridge-poles, chimneys and other elevated portions of the roof are connected by copper, galvanized iron or steel wires or cables. At several points there is connection with damp ground. The purpose is twofold: partly to prevent the disruptive discharges of electricity which we call lightning, and partly, if a bolt hits the building, to conduct it safely by an easy path to damp ground. Protection against damage and danger to human life when a lightning bolt hits a building belongs in the first stage, the passive one, when protection, not prevention or production, is the motive.

Frost protection is another illustration. Here no attempt is made to control the general conditions that bring the low temperatures associated with frost, but by means of cloth or other screens, or by the use of smoke clouds from fires, we try to protect sensitive crops from damage by checking radiation from the ground and the plants. The cloth screens over the tobacco in the Connecticut Valley, similar screens used in certain Mediterranean districts to keep fruits from ripening too fast and so to have them ready for market at the most favorable time, and planting coffee trees under the shade of other trees, such as bananas, in order to protect them from the tropical sun, are additional examples.

The planting of trees to serve as windbreaks is a characteristic undertaking on our western plains, and in many other places in different parts of the world. These windbreaks do not prevent the conditions that give rise to the high winds which are injurious to planted crops. They merely protect the crops on the leeward side by reducing the wind velocity. Studies of the climatic effects of such windbreaks show that, incidentally, there is some reduction of evaporation and a slight local moistening of the air. The high walls seen in many places in the Mediterranean countries of Europe are built to serve as protection against the strong winds of that area. These walls do not add to the traveler's enjoyment when he is anxious to see the gardens and orchards, but they serve their purpose satisfactorily and are excellent examples of man's efforts to secure protection against unfavorable climatic phenomena. Those who have journeyed through the lower Rhône Valley can not have failed to observe the rows of trees planted there to serve as windbreaks against the dreaded mistral, a strong northerly wind often reaching gale force, which has much in common with our northwest winds here. The mistral is the "master-wind" of that section of the northern Mediterranean coast. It is well known, and commonly

spoken of as one of the scourges of Provence. On our own western plains, the desiccating effects of hot winds during the summer, often seriously disastrous to growing crops of all kinds, can be decreased by windbreaks planted on the southern margins of the cultivated fields, while rows of trees on the north reduce the velocity of the cold northwest winds of winter and are a protection to the otherwise fully exposed farmhouses. Windbreaks, on whichever side of the buildings they are planted, furnish shade in summer and break the monotony of the great level open stretches of the plains.

The narrow streets of cities in the Near East are familiar to us all. They are designed to keep out the sun, and are often, in shopping districts, covered by awnings to serve as additional protection. In this country, in various cities, there are arcades lined with stores, and shoppers are thus protected from inclement weather. One of the advantages enjoyed by large department stores is the fact that so many different things can be purchased under one roof, without the necessity of going out when weather conditions are unfavorable. A rather amusing investigation has recently been made of the effects of rainy days upon the amount of business done by the larger department stores and by the smaller shops. It appears that if the day begins by being fine, but has rain about noon and in the afternoon, the department stores are the gainers and the smaller shops are the losers. The apparent explanation is that shoppers, especially those from the outlying suburbs, start to town on a fine morning, but if the afternoon is rainy or snowy, they naturally prefer to stay under one roof, and therefore do their purchasing in one store. On the other hand, if the day begins by being very cold or wet or disagreeable, both department stores and the smaller shops suffer loss of trade.

We turn next to the second stage, that of the effort towards prevention of conditions that would otherwise occur. This is, obviously, more active and aggressive than the first step, that of mere protection.

The campaign against frost goes back to early days, and is carried on wherever temperatures fall low enough seriously to damage valuable crops. "Frost-fighting" is the term that has come into use in recent years in the United States, and it is a very appropriate designation for this aspect of man's struggle against nature. Nowhere in the world has frost prevention been more thoroughly studied than in our own country. Nowhere else is the campaign carried on more scientifically or with so large an investment of capital. To-day's fight against frost is a carefully planned and an effectively organized undertaking. It is no longer the haphazard burning of piles of brush, straw and other rubbish, as in former times, when the formation of a thick cloud of smoke was the object sought. There were then no regular frost forecasts. There was no cooperation among neighboring farmers and fruit-growers. To-day, in this country, the Weather Bureau pays special attention to its general forecasts of frost during the critical times of the year, and in addition in many of the great fruit districts of the west special local observations are taken and used as the basis of local forecasts. Cooperation between fruit-growers in the same locality insures far greater safety to all than is the case when a single orchard or ranch is protected. It is a common fight against a common enemy, and is a cooperative campaign.

Frost-fighting may be seen in many parts of the country, and the methods used vary. In the cranberry bogs of the Cape Cod district of Massachusetts flooding is the natural, easy and most effective means of preventing frost damage. In the citrus belt of Florida, in the cranberry bogs of Wisconsin, in the famous apple district of southern Oregon, in many other districts and in the case of many other crops, the campaign against

frost is waged. But it is in that wonderful citrus fruit district of Southern California, in the general vicinity of Los Angeles, that the prevention of frost is most widely and most scientifically carried on. The climate of Southern California probably comes as near perfection as a climate can come, but there are some things, even in Southern California, that man would prefer to have changed. Frost is a potential factor of very great importance, relatively infrequent as it is. Where immense sums of money are invested in citrus fruits and in other crops, the prevention of frost becomes a necessity.

Many different methods of frost prevention have been tried, as by "smudges" of dense smoke from moist bonfires; by dampening the air, either by means of sprayers placed above the tree-tops, or by allowing steaming warm water to run through the irrigation ditches and channels; by keeping the lower air in motion, or bringing down warmer air by means of huge fans or blowers, and so on. The result of experience and of much careful experimental study has been to show that the safest, best, most effective and, in the long run also the most economical, plan is to use orchard heaters, burning crude oil. On a clear winter night, when the forecasts indicate frost occurrence, many thousands of these heaters are burning, and the sight, to those who are not accustomed to it, is one that will never be forgotten. It may be asked, "How is it possible, even with thousands of oil heaters, to keep the temperature outdoors above the danger-point?" The answer is that frost occurs on calm, or fairly quiet nights; the coldest air is near the ground, and only a comparatively thin layer has to be heated. If frost came on very windy nights, the air warmed by the heaters would be moved away, and cold air would continually be brought in. Under such conditions, any general warming of great masses of moving air would be impossible. It is the relative stagnation of the lower air on frosty nights that makes orchard heating practicable.

The expense of any such frost-fighting campaign is heavy, and includes the cost of the heaters, the fuel and the wages of the men who fill and tend the heaters. Therefore there is a limit to the number of times a winter that frost-fighting is worth while. It is not profitable if it has to be resorted to often. As a result of the vigilance of the growers in watching the readings of the thermometers in their orchards, and of the effective frost warning service of the Weather Bureau, the expensive application of the heating process can be so accurately planned for as to avoid a great waste of oil on the one hand, and the destruction of the crop on the other.

Hail is another climatic handicap whose coming man has often tried to prevent, for it may cause very serious damage to crops of all kinds. Various sorts of religious emblems or amulets are still hung on the trees by European peasants in the belief that such charms will prevent hail from falling. In Europe, for many generations, these and many other methods have been tried, from the ringing of church bells in the earlier days down to the "hail-shooting" and so-called "electric Niagaras" of modern times. "Hail-shooting" is still popular in some of the vine-growing districts of southern Europe. Here especially designed mortars are used, from which, when threatening thunder-clouds are approaching, charges of gunpowder are exploded towards the storm. There is much noise; vortex rings of smoke rise from the mouth of the mortar—and the hail falls, or not, as nature ordains. An enormous amount of money has been spent on this hail-shooting campaign. Special foundries have cast the mortars. And the belief persists that the firing is effective. Hail is the product of violent ascending and descending currents of

air in thunder-storms. These currents may rise, at considerable velocities, for thousands of feet. The explosion of charges of gunpowder on the earth's surface can not alter the condition of the great physical experiment which nature performs every time she produces a thunder-storm. Fortunately for man, hail does not occur in every thunder-storm, as common observation will show, and fortunately also, when it does occur, it falls over narrow strips of territory only, and never throughout the whole district covered by the storm. The so-called "electric Niagaras," or "hail-rods," are tall openwork steel or iron towers, erected in certain districts of Europe with the idea that they will in some way draw off the electricity from the clouds and prevent the formation of hail. The electricity developed in a thunder-storm does not affect the formation of hail; nor have the "hail-rods" any influence, one way or the other.

In speaking of protection against lightning as an example of the first stage in man's effort to control his climate, the fact was noted that modern methods are designed to protect buildings, when disruptive discharges of electricity occur, by providing a natural and easy path to the ground. The modern "cage" method has a second object, and that is to prevent as many disruptive discharges as possible by the flow of electricity from the ground up through the "cage" to, and then off from, the points on the roof. Excessive charges of electricity and flashes of lightning may thus be prevented.

Fog is another climatic element which is often a very serious handicap to man. In fact, with our present universal use of automobiles and trucks, and especially with the rapid development of aviation, fog is every day assuming greater importance as a factor in our activities. To prevent the formation of fog, or to dispel it when formed, various methods have been tried. In the laboratory, with small blocks of fog, the air can be cleared by electrical discharges, or by heating it and thus increasing its capacity for water vapor so that the water particles will disappear. But in the open air fog prevention is a very different matter. Within a few years experiments have been carried out in Pittsburgh with a view to preventing the formation of the river fogs which are there a serious handicap and menace to navigation. Oil was poured on the river, and the results, while not convincing, seem, within limits, to have had a slight degree of success. In France, coating the waters of the Rhône and of the Saône at Lyons with oil has not proved a practicable undertaking. The "steam" type of fog occurs on calm cool nights when the water in the river is warmer than the air above it. The warm air, rising from the water, contains much water vapor, and is chilled when it mixes with the colder overlying air. By mixture and conduction the cooling may be sufficient to bring about condensation into fog. The oil film serves in a way as a sort of cover or lid, and checks, to a certain degree, the "steaming" from the warm water of the river. This method is, however, applicable, so far as it is successful at all, to one type of fog only. It could not be used in the case of the common lowland and valley radiation fogs that form so often on clear, quiet nights, especially in autumn and winter, over the lowlands and in the valleys of a mountainous or hilly country.

Many fogs result from the cooling of the lower air which comes from a considerable distance and whose moisture is also derived from a distance. When such warm, moist air happens to be carried over a cold surface, it may be water or land, cooling takes place and condensation may result. Local evaporation over the locality where such fogs occur is not the cause of the fog. The warm

air brings the moisture with it. Of this type are the famous and much-dreaded fogs of the Grand Bank of Newfoundland, so familiar to transatlantic travelers over the northern steamship lanes. These fogs are mainly due to the importation of great masses of warm, moist air from over the warm waters of the Gulf Stream drift. As this air crosses the cold water of the bank it is chilled, and condensation into fog results. Unfortunately for navigation, the Newfoundland Bank area of the North Atlantic has almost ideal conditions for fog formation, especially in the spring and early summer. The causes of these fogs are far and away beyond man's control. Unless, or until, some way is found for locally dispelling the fog in the immediate vicinity of a vessel, the situation must remain as it is to-day, and always has been. It is true that experiments have been made in fog-dispelling on board ship by means of powerful electrical discharges, but however successful such a temporary local clearing of the air may be, the fog constantly keeps blowing in, and any cleared space is inevitably almost immediately again foggy.

In this country experiments have been made with a view to artificial dissipation of fog on flying fields by means of electrified sand dropped from aeroplanes. While the early press reports of this undertaking were favorable, there are several points concerning which conservative meteorologists are still in doubt. Electrified sand does seem to have cleared spaces in clouds, but on the other hand "holes" in clouds often develop normally in the processes of cloud formation and dissolution, and ordinary aeroplanes can clear a space through a thin cloud without the use of electrified sand. Whether reasonably successful or not, the practical fact remains that fog-dispersal by means of electrified sand scattered from aeroplanes is not a feasible method in the case of extended dense fog sheets, and the expense on a large scale is prohibitive. It is, at any rate at present, inconceivable that any general dispersal of such a fog as, *e.g.*, that which at times lies over New York harbor, can possibly be accomplished by this method. Electrical dispelling of fog on a small scale, both in the laboratory and even outdoors, can be accomplished. It is the magnitude of the task outdoors, and the expense of it, that stand as stumbling-blocks in our way at present.

In Europe, where commercial aviation began on a large scale earlier than it did in the United States, local studies of practical methods of fog dispersal on flying fields have naturally outstripped our own efforts in this direction. In England, for example, various methods have been tried, all on a relatively small scale, however. Heating the air, in order to increase its capacity for water vapor and thus bring about a clearing away of the water particles, has proved impossible. Keeping the air in circulation by means of large fans and blowers, and thus endeavoring to prevent the occurrence of a low-lying layer of cold air essential to the formation of an ordinary lowland or radiation fog, was also found to be impracticable, as was the attempt to drain fog-laden air off of flying fields. Experiments in fog-dispersal by means of electrical discharges and by explosives have not been decisive. So far, all the attempts to dispel fog by artificial means except on a small scale, and when all the circumstances are favorable, have proved unsuccessful. It is possible to dispel fog, but all methods thus far employed are too expensive and could not be employed on a large scale outdoors. The general problem of fog prevention and of its dispersal when formed remains for the future.

The third stage in man's efforts to control his climate and weather is the

most active and aggressive. In this, there are the attempts to produce a condition which is not present as the ordinary result of natural processes. We are here concerned, not with protection or prevention, but with production.

The artificial production of rain is doubtless the most wide-spread and best known of man's activities in this direction. Over much of the earth's surface rain does not fall in sufficient amounts, or at the proper seasons, to satisfy us. Rain seems to fall so easily when it does come, and clouds, which precede rainfall, are so common and seem to be so very close to the stage of rainfall, that it would appear a relatively simple matter to produce clouds artificially, or, if they are already present in the sky, to shake the rain out of them. For clouds, it must be recalled, are merely collections of millions of small water droplets, or of ice crystals. The question whether any precipitation takes place depends on the size, that is the weight, of the solid particles, and upon the possibility of their being able to fall through the rising currents of air which usually accompany cloud formation.

One of the popular aspects of this whole matter concerns the very common belief that battles produce rainfall, it being a general impression that in some way the heavy cannonading brings about precipitation. In all recent wars, this belief has found expression. During our own Civil War, in the Franco-Prussian War, during the World War, the opinion was expressed, over and over again, that rains followed battles, as effect follows cause. During the great war the question was often asked by highly intelligent people whether long spells of rainy weather here in the United States were not due to the war in Europe. And in England, not many years ago, certain agricultural organizations sent a communication to the British Admiralty, asking that the heavy gun firing during the regular autumn naval maneuvers in the channel be discontinued on the ground that it brought rains during harvest time. It is an interesting fact that, while in modern times, in the days of gunpowder and of other explosives, the cause of the rainfall has been sought in the heat and shock of the firing, the ancient Greeks, long before the days of explosives, also believed that fighting brought rain. They attributed the occurrence of precipitation to the moisture from the perspiring bodies of the troops. It was only in relatively modern times that gunpowder explosions were believed to be responsible. The fact of the matter clearly is that preparations for battle have usually been made during spells of fine weather, and the fighting generally begins while it is still dry. Then, in the ordinary course of events over most of the temperate zone, a few days of fine weather are followed by a general rain storm; the battle ends in, or may be closely followed by, rain. The origin of the popular belief is thus easily explained.

Two main lines of attack on the problem of artificial rain may be noted. One attempts to produce rainfall by means of explosions; the other has sought to produce rain-clouds by making fires. With the former method we have had a most humiliating experience in our own country. About forty years ago, as the result of successful political wire-pulling on the part of one individual, who was not a scientist, Congress was induced to make an appropriation of several thousand dollars for the purpose of making rain in Texas. The method used in these experiments was mainly to send up explosives by means of small balloons, and then to have the explosion take place at the cloud level. It was claimed that the shock of the explosions and the liberation of gases from the balloons would produce the rain. The re-

port, which, to our national disgrace, was printed as a Senate Document, was naturally highly optimistic. Rain was stated to have been produced on numerous occasions, and Congress was induced to make a second appropriation for another year's campaign. By this time, scientific men were becoming aroused, and a competent meteorologist representing the Smithsonian Institution accompanied the rain-making expedition. As was to be expected, his report was very different from that of the leader of the undertaking. It appeared that all that the explosions did was possibly to shake down a few drops of rain a little in advance of the time at which they would have fallen naturally, and that the general rainfalls which it was claimed resulted from the experiments were such as would have come in any case. This most unfortunate undertaking, sponsored by the Congress of the United States, did much to discredit us in the eyes of European scientific men. It is highly important that no such occasion should arise again.

The development of the typical cumulus cloud of fine summer days has long been known to result from the ascent of air warmed near the earth's surface—rising when lighter than the overlying air; cooling as it ascends, and, if sufficiently cooled, reaching its dew-point so that condensation takes place and the cloud appears. Each cumulus cloud is in reality "the visible top of invisible ascending currents of air." These fine-weather summer daytime clouds, with their familiar flat bases and great convex tops, are characteristic over well-warmed land surfaces. Water, being warmed much less than land under the summer sun, is therefore not, as a rule, favorable for the development of these clouds, although, near shore, they drift out over the ocean and in a different and much less massive form they are characteristic of the trade-wind belt at sea. It is an interesting fact that occasionally, when conditions are favorable, the hot air rising from fires may produce small, and sometimes even fairly large, cumulus clouds. I have myself seen beautiful illustrations of this in the case of the burning coal pockets of the Boston and Maine Railroad in Charlestown some forty years ago, and over a brush fire in Peru in 1897. Such clouds were well observed during the fire which followed the San Francisco earthquake, and they are not infrequently reported as forming over burning oil-wells.

About the middle of the last century, Espy, one of the greatest of American meteorologists, who was especially interested in storm formation by convectional ascent of warm air, seriously suggested that showers might be produced artificially, during summer droughts, if the farmers in the United States would unite in building huge bonfires of rubbish, or in burning large areas of woodland. In this way, Espy maintained, considerable masses of warm air would rise; cool during their ascent; form cumulus clouds, and finally reach the stage of rainfall. A story is told of an amusing incident in this connection. A party of engineers was constructing a road in a southern cane-brake. The day was intensely hot, and the negro laborers refused to work. The engineers said that if work was stopped, they would make a thunder-storm. The cane-brakes were set on fire, clouds formed, and, so the story goes, in a short time a small thunder-storm was in operation. The laborers were so much frightened because of this supernatural power on the part of the engineers that no further trouble was experienced.

In recent years there have been numerous so-called "rain-makers" who have plied their trade and often made large profits by contracting with farmers during a dry season to produce rain in return for a financial consideration.

The contracts are for so much money per inch of rain. These "rain-makers" are, of course, pure fakirs. They usually build a small wooden shack in some rather inaccessible locality, and from the roof smoke rises when the rain-making process is going on. The whole business is a distressing and disgraceful performance. Yet the surprising thing is that so many apparently intelligent farmers, in the western United States, in Canada and in Australia, have, even in very recent years, been hoodwinked. The "rain-maker" usually has sense enough to watch the official weather maps and forecasts carefully from day to day. If he sees that the general weather conditions are becoming favorable for rain he produces his contract, secures his clients' signatures obligating them to pay so many hundreds or thousands of dollars for an inch of rain, and appeals to them with the slogan, "No rain, no pay." It is an easy financial proposition for the "rain-maker." In a *Science Service* note, Professor C. F. Talman has called attention to an interesting suggestion made by Dr. David Starr Jordan which is directed towards positive assurance of the rain-maker's financial status. The rain-maker contracts to bring rain within a certain time, for a fixed sum. He should then take out weather insurance against a continued dry spell during that time. If the rain comes, the farmers pay. If it does not come, the insurance company pays. "Assuming the insurance premium to be less than 100 per cent. of the face value of the policy, and also less than the amount to be paid for rain by the drought-stricken farmers—conditions that probably could be met in most cases—the scheme is absolutely perfect."

On quite a different basis from all such attempts at rain-making by pure impostors are the scientific experiments with electrified sand, already referred to in connection with the fog-dispersal. It has been claimed that this method not only dispels the fog, but, by causing the small water droplets to join, produces rainfall. Here again, what may work as a laboratory experiment, or on a very small scale outdoors, is hopelessly inadequate to produce any large result. Professor W. J. Humphreys, of the U. S. Weather Bureau, has discussed this matter very clearly. The physical processes at work in bringing about our general rains are on an immense scale, and involve great masses of air, many cubic miles in extent. Our great storm clouds are produced by the forced ascent of immense masses of air. The water vapor is imported, often, from great distances. Producing larger drops in place of smaller droplets, locally, is not the line of attack for any effective result. Even small drops will fall if the ascending currents of air are weak and slow. Our general rains result from cooling, and continued cooling, of masses of air imported from a distance, and not from any local cause. Even if we could bring down, as rain, all the water in a great cloud mass overhead at any one moment, the resulting precipitation would be practically negligible. The experiments of nature which give the earth its beneficent rains are on far too vast a scale for man to deal with.

A very recent attempt to make rain was reported in a press dispatch from Hong Kong, June 15, 1929. That city was suffering from a serious water famine. The Royal Aviation Force and other agencies were to cooperate in trying to produce rain. "Two aeroplanes will ascend," so the dispatch read, "above the clouds and sprinkle a powdered chemical with a refrigerating effect, which it is hoped will precipitate the downpour." A later dispatch reported the attempt as unsuccessful.

Here we touch also the much-debated question of the influence of forests on climate, and especially on rainfall. If

man, by reforestation, can increase rainfall, he can in this way produce a change in his climate. This question is one of very long standing. For generations, at least as far back as the time of Columbus, the belief has been held that forests exert far-reaching effects upon climate, and that, therefore, deforestation, whether as the result of man's own efforts or because of fire, will bring about marked changes in climate. This popular notion gained great support in Europe at the time of the French Revolution, when there was a wide-spread destruction of the forest trees. So exaggerated have been some of the ideas on this matter that, as was noted earlier in this article, writers have seriously maintained that the cutting down of trees on our northern Pacific coast has affected the climate of Europe. Of course, no intelligent person has any such idea today. Forests are merely one kind of surface cover, and while the climatic conditions within an extended forest may be slightly different from those in open country not far away, it would be preposterous to suppose that a forest climate, if there is such a thing, can be transported to a distant region.

The reason for the world-wide prejudice as to forest influences is somewhat difficult to determine. It is likely, however, that because forests are usually found in regions of fairly heavy rainfall, it has seemed that the forests produce the rain. The world's forests do grow where the rainfall is greater than it is over the grasslands and the deserts. Furthermore, forested areas are as a rule found where the humidity is higher, where there is more cloud and where the temperatures are somewhat less extreme.

In dealing with this question, the historical method of treatment has in the past been very generally adopted. A forest once existed in a region where now there is no forest. Tradition, or historical record, establishes that fact. In this same region the climate is not what it once was. People say so. It is universally accepted as beyond a doubt true. Hence, the removal of the forest produced the change in the climate. This is a fair outline of the general run of the historical argument. Nothing here is clearly and beyond a doubt established. Especially in the case of a supposed change of climate, there is no instrumental record to prove it. Everything is vague and uncertain—scientifically wholly worthless. The literature on the forest-climate problem is a very extensive one. It is interesting because of the extraordinary variety of opinions which it includes and because of the unreliability of the evidence upon which the conclusions are based. Except for its value as an historical survey, all the writing on this subject is negligible until the last few years.

Clearly, no student of climate will, or should, be satisfied with any evidence in this matter that does not rest upon accurate instrumental records. Tradition, hearsay, even historical records, are negligible. The whole controversy in regard to forests and climate has, within the last few decades, entered upon a new phase. The increase of meteorological stations all over the world has brought us instrumental records not available in the earlier days of this great controversy. Furthermore, in Europe especially, but also in India, in Java and elsewhere, stations have been established under the forest trees, in forest clearings and in open country surrounding forests, for the express purpose of comparing the conditions in forests and elsewhere. In addition, the climatic effects of deforestation and of reforestation have been studied by the most approved modern methods, under the supervision of competent scientific observers and in connection with official meteorological organizations. Upon such instrumental records, and upon

them alone, does the climatologist rest his case. The speculations of former times have been discarded, interesting as many of them were. We now have enough definite information to enable us to state certain well-established facts. What are these facts?

First, as to temperature. The observations indicate very clearly that, in temperate zone forests, the average temperature for the year is slightly lower, a degree or so Fahrenheit, than that over open land near by. In summer, forests are a few degrees cooler by day, probably chiefly because of the decreased evaporation and not because of the shade, and they are somewhat warmer by night. In winter, minimum temperatures in forests are a little higher than those in the open. Some observations in Arizona and New Mexico show that all extremes both of heat and of cold are somewhat modified under the forest trees. The differences as regards temperatures are clearly very small. In connection with this matter we should remember that the temperatures that we feel—the so-called "sensible temperatures"—by no means correspond directly to the temperatures as recorded on thermometers. We are affected, in our sensations of heat and cold, by many factors that do not influence the thermometer, such as conduction, radiation and evaporation, as well as by our physical condition, our clothing, exercise, and so on. When we leave a hot dusty road on a summer day and walk through a forest we have an agreeable sensation of finding it cool, but it is not a lower air temperature that affects us. It is the fact that we are in the shade. Again, on a cold, raw, windy day, forests seem much warmer than the open, but this apparently higher temperature is not indicated by the thermometers. It is due chiefly to the fact that we are out of the wind and are therefore losing less heat by conduction. The actual temperature differences between forests and the open are, as has already been indicated, slight. They are, in fact, too small to be felt, in most cases. Our sensations are not reliable indices to actual temperatures.

As regards relative humidity in forests, the results of observation show clearly, as is to be expected, that the air under the trees is somewhat damper (from 5 to 10 per cent. on the average) than that in the open, and that evaporation is less, doubtless chiefly because of the decreased wind movement.

The crux of the whole forest-climate controversy is in connection with the possible effects of forests upon rainfall. Temperature, humidity and evaporation are but minor, perhaps almost negligible, factors. Here again the climatologist rests his whole case upon the results of observations, provided those observations are made with accurate instruments, under proper supervision and exposed in accordance with established rules. Such observations are available for several European areas. Unfortunately, our own country is far behind Europe in this whole investigation. All the earlier cases in which there were apparent evidences of considerable influences of forests upon rainfall have been discarded because the records were unreliable. The best European rain-gauge records now available indicate that forests do have an effect in increasing the rainfall, but only to a very slight degree. It is true that the rain-gauge readings in and close to forests show an excess of between 2 and 10 per cent. of the annual rainfall as compared with open fields near by, and also indicate a slight increase as the result of reforestation. But careful checking of the observations shows that much, or most, of this difference is due to the difference in the exposure of the gauge, and when allowance is made for such instrumental errors, the increase in the local rainfall

due to the forest is not more than 1 or 2 per cent. This is, obviously, an almost if not entirely negligible effect. There are those who believe that further observations are unnecessary, and consider the case closed. The majority of climatologists, however, are anxious to have many more observations, especially in the United States and in the tropics, for up to this time we in this country have contributed little toward the settlement of the controversy, and there is need of additional data from tropical forests. The forests of Arizona and New Mexico, where some observations have been made, seem to have no appreciable influence on precipitation. At Marietta, Ohio, there are rainfall records extending back about one hundred years, to a time when that district was forested. Yet the average precipitation of the first fifty years was less than 1 per cent. greater than the average of the last fifty years.

A conservative view of the whole situation would seem to be this. The question of the climatic effects of forests is still, to some extent, an open one. The available instrumental observations indicate slight effects, on temperature, humidity, evaporation, wind movement and rainfall, but the instrumental data are still few. It may be, although this seems very unlikely, that more widespread and more complete observational data will somewhat change the situation as it appears to-day. One thing is, however, clear. The extravagant claims made by various writers in favor of forest conservation and of reforestation on the ground that forests have a very marked influence in increasing rainfall have no support in the available observational results. This does not mean that we should not develop our national forest conservation policy, or that forests have no effect upon erosion and floods. The relations of forestation and of deforestation to run-off, erosion, high and low water and similar problems do not directly concern the climatologist. His immediate responsibility ceases when he honestly states his conclusions regarding forest influences on climate. There seems to be no possibility of definitely establishing, or of definitely disproving, the contention that deforestation on the southern Appalachians must bring about a decrease in rainfall over the eastern half of the United States. We are here dealing with the conditions of immense masses of atmosphere, over great distances, without the possibility of instrumental record. The conservative view, based on known facts of forest influences elsewhere, would seem to be against any appreciable effects of the kind here referred to.

There is one other effect of trees upon moisture to which reference may be made. This is not a case of increasing rainfall, but of collecting water droplets already in the air, as the result of a general process of condensation with which the trees have nothing whatever to do. What I have in mind takes place where fogs or clouds drift through or are present among trees or bushes. In such cases, the leaves and twigs may catch and collect the water droplets to such an extent that there is actually a fog or cloud drip to the ground underneath the trees. Numerous cases of this kind are well known. In the dry summers of California, for example, in the coastal fog belt, the fog drip may often be seen, and serves to keep the soil damp and the vegetation green in the immediate vicinity of the trees. Thus, in the redwood district, on the immediate coast, the trees are often so wet that the fog-drip is like a very light rain. The vegetation on the hills of Berkeley shows similar, but less marked, effects. Table Mountain, near Cape Town, when covered with a cloud, has a well-known "cloud-drip." Other cases have been

described by numerous writers on Green Mountain on the island of Ascension, and in the Hawaiian Islands. The "rain tree" of Ferro, about which many stories have been told, doubtless is to be explained as a case of fog-drip, and the "dew ponds" of the English downs are kept wet not by dew but by fog-drip. Such effects, it should be noted, are very local, occur only where the necessary elements of fog or cloud and of trees or shrubs are present and are not world-wide although they do have a certain local importance.

The question: How far can man control his climate? is, then, briefly answered as follows. We can, here and there, by methods developed as the result of experience and of study, protect ourselves against or prevent the occurrence of certain conditions which are disagreeable or dangerous to us, or are injurious to our crops. We can not produce rain, or change the order of nature. But where we have succeeded, as in frost prevention, for example, the results are of very great economic significance. That the future will bring further advances in the way of controlling local climates is certain. There is no hope, however, of our ever being able to bring about any but local modifications. To repeat Sir Napier Shaw's statement: "We are lords of every specimen of air which we can bottle up or imprison in our laboratories. . . . In the open air we are practically powerless."

FRONTIERS

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AFTER writing *Frontiers* at the head of my first sheet I recalled that this was also the title of Lord Curzon's Romanes Lecture delivered about twenty-two years ago to the young men of the ancient University of Oxford. Lord Curzon spoke of geographic and political frontiers, and urged the young men of Oxford to take their part in the responsibilities of the wide-flung boundaries of the empire. It is more fitting and more pertinent to the present needs of our American civilization to consider the frontiers of science.

As a background for a discussion of the frontiers of science it is proper to recall that the geographic frontier has been until recently the most ever-present and compelling reality of our American history. It is significant that Lord Curzon lays almost equal stress on the frontier as a factor in English history.

While Lord Curzon's vast colonial experience has led him to treat his problem much more as an American might have done than would have other European writers, there is nevertheless an unmistakable difference between his treatment of the frontier and that which would be accorded the same title by an American. May I suggest that this is due to a difference in the European and the American conception of the frontier? In Europe they cross the frontier. In America we penetrate the frontier. In Europe they think of the defense of the frontier. In America we plan for its development.

To the American the term frontier suggests no specific geographic boundary, for the great frontier line has been constantly shifting. Instead, it calls to mind the musket, the rifle, the pack saddle and the canoe, the deep woods and the open prairies, the fields of frosty snow and the sands of heated deserts, the seemingly limitless plains and the seemingly unending defiles of rugged mountains. Above all it recalls the frontiersman. To the American the term frontier implies the borderline between what is known and what is unknown. It can not be conceived of apart from those hardy, fearless and independent men who penetrated the wilderness and who by their daring made possible the development of a west and the regeneration of an east that was approaching decadence.

To be sure, the frontier long ago moved beyond the gaps of the Appalachians, and the regions lying to the east of these barriers have largely ceased to be conscious of the influence of the old frontier, notwithstanding the fact that they are in no small degree dependent physically and intellectually on the new west which has so swiftly replaced the old frontier. Even west of the Mississippi it is, in our day, only the botanist, the zoologist and the geologist who have the privilege of seeing with their own eyes something of the life of the old frontier, yet in a large way the forward movement of the frontier may be said to have until recently dominated our national life.

I have referred to the development of the west because in America the great frontier movement has been to the west. In a way "the west" has, indeed, been synonymous with "the frontier." The full magnificence of the great westward movement can be realized only when we recall that the statement that the movement has been toward the west is true only in the average or statistical sense. In detail, the movement was most com-

plicated. Along the St. Lawrence and over the Great Lakes the French pushed their canoes to the valley of the Mississippi and, with a line of outposts, cut the continent in two. In the southwest the Spanish had established their settlements on the Rio Grande and Gila and on the southern Pacific coast. In the northwest Russia had secured a foothold and had laid claim to a part of what is now California. Hence the venturesome vanguard of the English-speaking people of the Atlantic seaboard had in its westward movement to cut and to obliterate the frontiers established by those who differed in race, language and religion. The great human tide of frontiersmen moved forward not merely over geographic barriers, against the force of great biological obstacles and against the resistance of primitive men, but also against the opposition of social and religious prejudices engendered of historic political differentiation. This cutting and obliterating of old frontiers by the great westward movement has furnished some of the most thrilling chapters of our national history.

The westward flow of the human tide and the transformation of our great continent have been so rapid that the most of us have not yet realized its full significance. As compared with most of the changes with time in history, it has been almost instantaneous. The swiftness and magnitude of the transformation may be grasped when we contemplate the western half of our continent as we see it to-day, and then recall that as late as the early years of the nineteenth century many thoughtful writers considered our possession of the entire trans-Mississippi region as important primarily because it would protect the habitable region to the east against the encroachment of some rival power.

This may seem to be history, not science. It is not, however, foreign to my present theme. The development of our vast American wilderness has been due in part to the hardihood of our frontiersmen of exploration and our pioneers of settlement. In large part it has been due to the application of the results of the research of frontiersmen of science.

Geographically, our western frontier has passed into history. Intellectually, the passage of the geographic frontier is a loss. The exploration of the west stimulated the imagination. The settlement of the west hardened the muscles and strengthened the moral courage of our forebears. The resources of the west made possible the development of independence of thought and action. It is the conviction that we must find some moral equivalent for the old frontier in our new social, intellectual and spiritual life that leads me to consider the frontiers of science.

Frontiers of Science

In science as in American history the conception of the frontier is inseparable from that of the frontiersman. In science as in history the frontiersman creates the frontier.

Men of the old frontier were of the most diverse sort. Many of the men in buckskin and homespun were merely camp-followers of the real frontiersmen of the west. The analogy must not be too closely drawn between the men of the old border and the frontiersmen of science. The frontiersman of science has in common with the true frontiersman of the American wilderness an unconquerable desire to penetrate the unknown, the courage to follow an individual vision and an exultation in doing the things which others know can not be done.

Not all the lines of Kipling's "The Explorer" measure up to the title, but two of the eighteen verses seem to me to describe graphically the scientific frontiersman as well as the frontiersman of the geographic border.

> "There's no sense in going further—
> it's the edge of cultivation,"

So they said, and I believed it—
broke my land and sowed my crop—
Built my barns and strung my fences
in the little border station
Tucked away below the foothills
where the trails run out and stop.

Till a voice, as bad as Conscience,
rang interminable changes
On one everlasting Whisper
day and night repeated—so:
"Something hidden. Go and find it.
Go and look behind the Ranges—
Something lost behind the Ranges.
Lost and waiting for you. Go!"

Not all men trained in the routine of scientific research can be frontiersmen of science, but only those who have the rare capacity to hear the one everlasting whisper, day and night repeated, so:

Something hidden. Go and find it.
Go and look behind the Ranges—
Something lost behind the Ranges.
Lost and waiting for you. Go!

To those who do hear and who are willing to make the necessary sacrifices the possible frontiers are boundless.

It seems to be worth while to classify some of the frontiers as they exist to-day. In a few years, the advances of science may have been such that a new group of frontiers will be open.

The Obvious Frontiers of Science

The most evident frontiers of science are those associated with the frontiers of geographic exploration. When the word "unexplored" occurred frequently on the maps of the world, men of science often experienced the hardships of the wilderness. They were frontiersmen both physically and intellectually.

The Golden Age of Science that produced Darwin and his eminent contemporaries was an age of geographic exploration—an age when frontiersmen began to create frontiers in the forests, deserts and swamps of North and South America and of the Dark Continent. Geography, geology and the natural history of plants, animals and man were their dominant interest, but it is my belief that their discoveries had a profound influence in stimulating research in other branches of science.

I also believe that the stimulus of the scientific exploration of our own western frontier has played a part not fully realized in our own intellectual development. For example, only a century and a quarter ago Lewis and Clark set out on the great expedition which opened vast areas of the west to scientific exploration. More significant than the fact that their letter of authorization was drawn by the president of the United States in person was the interest of the American people in their explorations. A study of the literature of our western exploration of a century ago furnishes indications of a public interest in science the significance of which has, I think, not been fully appreciated.

Lack of time precludes the listing of the naturalists and geologists who with the fur-traders, with Custer or other military leaders, with the wagon road or the railroad exploring parties or alone with their own blankets and rifles braved the hardships of our western frontiers in search of scientific knowledge. Their work was simple, but it was fundamental. The details of their contributions have long been covered with dust, but their interest in research and their accomplishments under difficulties fired the enthusiasm of their contemporaries. They were few in number, but their spirit of adventurous research still lives in men of to-day who could trace their intellectual inheritance to the scientific frontiersmen of the early days.

The incidents of the physical and moral courage of the naturalists of our old frontier would make an inspiring chapter in the history of science. Let one example which illustrates leadership as well as courage suffice. John Wesley Powell knew that the Grand Canyon of the Colorado should be explored. He might have left the task for some man

with two usable arms, since he had only one. But when he had led the main party as far as they could go without entrusting themselves to boats on a voyage through the unknowable perils of the chasm, his men placed strength of moral courage above the strength of physical completeness and every member volunteered to accompany the leader who had sacrificed one arm in the service of his country and was willing to risk his life in the service of science.

With the passing of our geographic frontier, the physical pioneering on our own continent was largely completed. We shall never again have living and working within our own border such an honorable list of naturalists of the blazed trail as that which might be written for the past century.

But what of our responsibility for the wildernesses of South America, the islands of the Pacific and the great scientifically unexplored regions of Asia. In the attack on these obvious frontiers more than exploration is necessary. A group of able men in the museums and herbaria is essential. Notwithstanding our national wealth we are but pitifully equipped in such specialists. Great collections must go to Europe for study, because we have not the trained men. This is a serious state of affairs for American science. The first results of biological exploration become the types or standards to which all later specimens must be directly or indirectly referred. If these remain in America, we have the bases for great developments in the future. If we allow them to go elsewhere, our future students must go to Europe to study what our own explorers have collected. Some of our industries are now suffering because of our lack of foresight in developing our knowledge of the biological resources of little-explored regions. Our prestige in South America and in the Pacific will suffer if we do not recognize our opportunity.

Frontiers of Laboratory Science

But frontiers of science are not necessarily associated with geographic frontiers. Willard Gibbs, moving quietly, unknown and unnoticed, among his academically prominent associates of Yale, was as truly a pioneer as Daniel Boone or Kit Carson.

As the wilderness gave way to the city and as the power of specialized techniques of research became known, it was inevitable that the laboratory should replace the camp. Thus while the scientific frontiers of the geographic border are the more obvious pioneering, it was inevitable that in time the achievements of the pioneers of the laboratory should come to be the more widely recognized.

The building of laboratory walls about the scientist merely widened his scientific frontiers. He refused to look at the walls—he saw only the vision of the wilderness of problems which he might try to solve with new equipment. His prowess has been unbounded.

The astronomer has analyzed the heavenly bodies as well as charted their positions at present and determined their courses for the future. The physicist has enabled us to hear the voices of our friends across a continent and to look at the shattered bones of our bodies through our flesh. On one frontier the chemist has sought and found new elements; on another he has formulated the behavior of ions in solution; on another he has synthesized by tens of thousands compounds which he once supposed could be made only by some mysterious vital force within the bodies of living organisms.

The biologist did not cease to be a frontiersman when he traded in the old rifle or fowling-piece for the new microscope. The description of the anatomy of the tissues was but a prelude to the tracing of their development from the egg and the sperm. Even the egg and the sperm could not be taken as the be-

ginning. Biological frontiersmen were not satisfied until their structures and development were known. In the biological laboratory, physics and chemistry have been combined with delicate manipulative experimentation which has become a part of every field of research on living organisms. The interrelations of hosts and parasites, both plant and animal, have been unraveled, with vast profit to mankind.

To list again the accomplishments of the frontiersmen of the quiet laboratory would be to recount achievements which have become the commonplaces of the history of science. Instead, I would like to formulate some conceptions of the frontiers of science which are not so apparent or familiar.

The Laboratory on the Geographic Frontier

In the development of biological science there is still a great frontier which must be attacked before the physical frontier has disappeared.

Science has lost irreparably because adequate collections of plants and animals were not made before the inroads of civilization deprived us forever of the opportunity. Powell, in founding and carrying the burden of the Bureau of American Ethnology, was as truly a scientific pioneer as when he entrusted himself to the chasm of the Colorado. Notwithstanding his vision we have forever lost the opportunity of obtaining the full details on which an adequate knowledge of the American Indian must depend.

It is too late to repair these losses. It is our duty to see to it that we do not lose the opportunities which are still open to us for work on plants and animals in their natural habitats. Scientific men of our day will not be content with the natural history that satisfied the early pioneers of botany and zoology. They must have the precision of the laboratory. But it is clear that many of the most urgent problems of biology are in the field. The solution is unique and simple. Frontiersmen of our day must take the methods and equipment of the laboratory into the field.

I can write on this subject with conviction based on my own experience. A main personal botanical interest has lain in the investigation of the physicochemical properties of the plant tissue fluids which are of importance in determining the distribution of natural vegetation.

Space will not permit even a superficial review of the results of the series of investigations which have extended from the rain forests and coastal deserts of the Island of Jamaica through the mesophytic, hygrophytic and xerophytic habitats of North America to the Hawaiian rain forests. It is sufficient to say that the light which these studies have thrown upon the intrinsic factors determining the distribution of vegetation has fully justified the cost in funds, time and personal effort.

Out of these pure science researches has grown the conviction that the physicochemical properties of the plant tissue fluids are of fundamental significance in determining the adaptation of agricultural species and varieties for cultivation under varying soil and climatic conditions. I can not give here the scientific results of the years of study devoted to agricultural plants in our western and southwestern deserts. The highest personal results of these months spent with laboratory equipment in barns, garages, rotting boat-houses and in tents in the open air are twofold.

First, they have led to the establishment of my early convictions that the problems of plant geography must ultimately be written in terms of the physical and chemical characteristics of the plant organism as well as in the history and physical factors of the environment, and that these results obtained in the pursuit of pure science may be of human importance when applied to agriculture.

Second, they have driven home to me the conviction that one must seize such opportunities before it is too late. A few days ago I rode swiftly over splendid boulevards through the golf courses and past the great hotels and luxurious mansions of a southern city which has buried and obliterated for all time the swamp and the strand scrub through which I pushed my way with machete and knapsack only a few years ago. My notes contain all that will ever be known concerning certain features of the vegetation.

In scientific candor let us admit that this case is extreme. In equal candor let us recall that all over our national domain changes in natural conditions are swiftly taking place, and let frontiersmen take the methods of the laboratory into the field before it is too late.

The Frontiers of the Interfaces of the Sciences

As Americans we conceive of the frontier as the fringe between the mapped and the unexplored. In science the frontier is not merely the boundary between the known and the unknown in any great and formally recognized branch of research. It may be the interface of two highly developed sciences. Here I am tempted to illustrate by analogy. Oil and water shaken together remain oil and water still. Each has its own chemical composition, and within the three dimensions of space occupied by each substance as such each has its own physical properties. But at the innumerable surfaces where the oil and the water come into contact special physical forces are in operation. Furthermore, if some substances which are soluble in the two liquids—oil and water—be added to their respective solvents before they are shaken together to disperse one liquid as fine droplets throughout the other, these dissolved substances appear to behave in a very orderly way at the frontiers of the respective solvents. Such phenomena are not limited to the surface of contact of the two liquids. They are found to some extent whenever a solution comes in contact with the walls of a beaker, or with the air above. This multitude of problems was scarcely thought of a few years ago. Technically they are known as the problems of the interface. They might as well be called the problems of the frontiers of the solutions.

Now in the development and differentiation of science new fields are apt to be opened up by some imaginative leader—by some frontiersman of science. Others contribute details. A new terminology is developed and the science congresses are like the latter days of the Tower of Babel. The high specialization necessary in any branch of science isolates it for a time from other branches. Intensive development creates frontiers or barriers. This isolation has always been present in science. There was a time when astronomy was largely independent of physics and of chemistry, when chemistry had no bonds with physics and when biology had no place for either physics or chemistry. In our day the great sciences tend to break up into highly specialized fields. Theoretical physics has its own language. Genetics seeks an independent status.

An inevitable result of specialization is that after a time the development of a given branch of science seems to its workers to be at an end. But this is the very moment when the problems of the interface must be attacked. Physics must be brought to the service of astronomy, chemistry and biology. Chemistry must find its way into biology. Morphology must be considered in the light of physiology. The physiologist must draw upon physics and chemistry, and must wake up to the fact that his science is no science at all if structure as well as function is not taken into account.

I like to think of scientific research as a problem in dimensions. Any single

method or any narrow field of specialization may be considered one-dimensional. Thus if two different methods be employed the investigator is working in two dimensions.

One-dimensional research has been so fruitful in the past that we have overglorified the importance of specialization. It often happens that the results of specialized research do not attain their fullest importance until they are considered in connection with the results from a quite different field.

For example, hybridization was developed as an independent field of scientific research. When I was a student, cytology was being hailed as the newest line of specialization—the highest refinement of anatomy or morphology. But cytology might now be a rather obscure phase of biological science were it not for the fact that students of genetics are seeking to find in physical structure some basis for the interpretation of the results of experiments in hybridization. Thus genetics must develop with due regard to the dimensions of two formerly independent fields of specialization.

If three lines of specialization are involved the solution of problems becomes three-dimensional. For example, William Bateson raged when W. F. R. Weldon ventured to calculate probable errors for the sacred results of Gregor Mendel. Now it is only the high and mighty in genetics who can disregard such criticism of the significance of their results. Genetics is developing in three dimensions—experimental hybridization, cytology and mathematical analysis.

Each new field of intensive specialization merely adds one more to the number of dimensions which must be considered by those who are working on the frontiers of the formerly independent branches of science and striving to bring unity out of chaos.

Let us draw another illustration of a somewhat different kind from the science of botany. Suppose that we consider the mapping of the distribution of the vegetation of the earth. We say that the plants are distributed over the surface of the earth. Thus theoretically it would seem quite simple to map the occurrence of species and larger groups in two dimensions of space.

Such a vegetation map is, however, largely meaningless unless we take into account the differences of temperature which are associated with elevation above sea-level and with distance from the equator. This adds another space dimension to our map. Again, the degrees of longitude and latitude and the contour lines of the map of the geographer give no information concerning the physical and chemical properties and water content of the soil. These properties are of fundamental importance in determining plant distribution. Thus the dimensions of water content, physical properties and chemical composition of the soil must be scaled on our map as additional dimensions. Our map has, in short, changed from a distribution in two-dimensional space to a map in many-dimensional space.

But even the foregoing dimensions are not adequate. The earth's crust is not static. It is subject to perpetual change which affects the distribution of plants. Conversely, the vegetation determines in some measure the changes which take place in the physiographic features. The physical and biological systems are not independent but intimately interrelated. Furthermore, living plant species are the present-day descendants of floras of ancient times. The distribution of the present is not independent of that of the past. No map will convey an adequate picture unless all these dimensions of time are represented.

This illustration has been drawn not for the purpose of depicting the complexity of botanical problems but to show the many lines of contact between the various sciences. Geology, meteorology, physics, chemistry and physiol-

ogy all have lines of contact in the adequate mapping of vegetation. Along all these interfaces between botany and the other sciences there is room for pioneer work.

The fruitfulness of research on these frontiers which represent the borderlines of different sciences is perhaps best illustrated by the frontier where biology and mathematics meet. It is but relatively a few years since these sciences were generally supposed to have nothing at all in common. Mathematics had found its place in astronomy, physics and chemistry, and these were known as the exact sciences. Biology, on the other hand, was called a descriptive science.

It is needless to say that the frontiersman who had the courage to assert that biological research must be prosecuted by mathematical methods had to contend against the most determined and bigoted opposition. Support was refused. Publication space was denied. Results were ignored or misrepresented. Mathematical biologists were criticized on the ground that the problems which they considered were not biological problems at all, the critics thereby evidencing their own incapacity to grasp the real possibilities of biological research. As work on the development of mathematical theory adequate for dealing with biological problems has advanced the biological problems themselves have widened.

The accomplishments of mathematics in biology have been so great and so varied that we dare not enter on the task of a review. For nearly thirty years I have not been particularly interested in any one specific biological problem. I have been interested in what I have felt was the more important problem, *i.e.*, the problem of the method of solving biological problems. During this time I have never come into contact with any biological investigation which could not be at least supplemented by mathematical methods. Prophecy is always dangerous, but I would like to be written down as having said that no biological problem of significance will be found in which mathematical methods of description and analysis will not ultimately be applied.

Biometry is entering a far broader field of influence. It early became a factor in psychology. It must ultimately contribute what is quantitative in sociology. Physics is now using the same theories of probability as those which underlay the development of mathematical biology. Pure mathematics is beginning to feel the influence of the mathematics developed for biological application. Finally, the philosophy which underlies the mathematical theory which has been developed for biological research is now beginning to influence our outlook on all scientific research.

Frontiers of the Application of Scientific Research

I have tried to show that the frontiers of science are not limited to the geographically regional, nor yet to the outer fringe of a single highly developed laboratory science. There are new frontiers of research to be created by those who have the fortitude to take the methods of the laboratory into the wilderness. Finally, there are vast frontiers of the highest promise for those who can master the perplexities of the interfaces between our established branches of science, thus making it possible to write our knowledge of the universe in fewer but more comprehensive equations.

But the frontiers of science are not limited to the boundary line between the surveyed and the unblazed in a specific field of research, nor to the undetermined relationships between two or more highly developed fields of research. The frontiersman of science may traverse either of these wildernesses for the exultation of seeing and recording what has not before been seen or of grasping and formulating relationships not heretofore

conceived. On the other hand, he may be fired with the idea that in the last analysis science has a human service to render.

There are frontiers of application of science to human welfare as well as frontiers of research.

It is worth while to consider first the so-called fields of practical application. Economic application would perhaps be a better term, for those things which count for the enlightenment and intellectual inspiration of mankind are quite as practical as those which contribute to physical comfort.

Since it is impossible to list all the frontiers of the application of the results of scientific research, it will be interesting to consider some of the new frontiers of application which have been created by the movement of the vanguard of population across the continent. Such new frontiers have been created by every stage of social development which has followed the penetration of the wilderness.

The pioneer was prodigal in his waste of natural resources. To his view the horizon of natural wealth was boundless. Why should he conserve the forests when no one knew their extent? Why fertilize the acre when a new acre of virgin soil could be cleared to replace the one exhausted of its fertility? Why think of the future of the range when cattle and sheep by the hundreds of thousands pastured at public expense meant private gain?

The need of these resources which we begin to feel to-day will become acute in the future. But the replacement of forests, the restoration of the fertility of the soil, the rehabilitation of our range and the reduction of dangers from floods due to the disturbance of natural conditions are not to be accomplished by the appointment of commissions of politicians with highly paid secretaries and budgets for inspection of the work of similar commissions in other states. They can be accomplished only by the basis of the most diverse kinds of research on as yet practically untouched frontiers of biological science.

In grappling with these problems more than science as we conceive it to-day is required. These are not problems of biology alone—they are problems of the application of the results of biological research under difficult economic and political conditions. It is here that some new type of man must establish his interests on the frontiers of biology and economics.

But new frontiers of the application of the results of biological research are not solely those called into being through the uncurbed exploitation of our natural resources by the vanguard of settlement.

Our growth has been so rapid on the scale of time as conceived by the historian that the blue smoke from the cabin chimney in the clearing had hardly faded away before the black cloud from the smokestack sifted its grime over the cottages of the laborers in the mines and the mills. Centers of population grew apace and solid blocks of grain and orchard were required to load the trains that carried food from areas where it could be grown to the industrial centers where it might be consumed. The old frontiers of human settlement thus vanished, but new frontiers of scientific application sprang into being. The orchards and crops that were free of disease when grown in the isolated patches of the settler became the paradise of fungus and insect when grown in solid blocks of miles. Food deteriorated or perished in transit. Paragraphs would be required to list the specific biological problems which have been created by urban development. Epidemics swept the crowded cities, and means of prevention had to be sought and made effective. Streams were polluted by sewage, endangering the health of those below. Glowing filaments replaced sunlight and the flickering candle, and new problems

of the physics and physiology of vision forced themselves upon the attention of the investigator.

Noble work has been done, but trails have hardly been broken in many of the new frontiers for the application of science created by the needs of new and ever-changing conditions.

Frontiers of Scientific Education

The frontiers of science are not limited to research and to the application of the results of research. There are also frontiers of scientific education. I do not refer to the technique of science teaching, but to the greater problem of making science a more important factor in our future economic, intellectual and social life.

One such frontier is the enlightenment of the public as to the significance of pure and applied science. It is too generally assumed that applied science is of human value, while pure science is of merely academic interest. Those who hold this view are blind to two great principles.

First, science has an intellectual significance in the development of our culture which is independent of its material contribution to our comfort.

Second, the actual relationship between pure and applied science is such that pure science research lays the foundations for application. Scientific men are often urged to prune the many-branched tree of research in order that it may bring forth the fruits of practical accomplishment more abundantly. Those who recommend the pruning-knife should understand that if it is applied to pure science it will be the roots which nourish the whole tree that are lopped off.

Another frontier for those who feel the call of scientific education is that of a serious and sympathetic attack on the old idea that science lacks esthetic value—that science is unimaginative, if not sordid. Science has by virtue of its practical human service taken its place alongside the humanities, but there are still those who feel that it is not one of the humanities. They assert that science must be humanized.

If science were valuable only as it makes two blades of grass to grow where but one grew before, only as it gives us the results of the election before the dawn of the day after the ballots are cast instead of a month later, only as it distributes the latest syncopation from the grill room to drown out meditation by our firesides, I might agree that science has not won its place among the humanities. But it is only the superficial observer who fails to see the beauty in science beneath the mechanism and the detail.

Two familiar cases will serve to illustrate.

I do not know whether the discovery of Neptune has carried with it any practical advantage to mankind, but to me the location of an unknown planet by mathematical reasoning and the experimental verification of the deductions by the telescope is far more dramatic than anything which we know in literature.

It is fortunate for the United States that we have in our own boundaries the richest known supply of helium. It is practically important that the wells be capped and the precious non-explosive gas be conserved. But the importance of the existence of helium in quantities sufficient for aerial navigation dwindles into insignificance in comparison with the intellectual value of the fact that science made it possible to discover helium in the sun before it was found on the earth. That helium could be detected in the sun before it was found on the earth makes us as human beings worthy to look down on the earth as we fly through the clouds.

One may define *humanities* in such a way as to include or to exclude whatever one likes. Those who care to do so may exclude from the humanities the inspiration of the discovery of Neptune, of

helium, of radium, or of the formulation of the idea of the orderly development of the biological universe. Whether science belongs to the humanities or not, the equation for human physical development, human inheritance and human behavior must be written in the terms of quantitative science.

In all these things there is the highest esthetic value—the beauty of magnificent orderliness.

To be sure, many have not the capacity to see the beauty beneath the apparent confusion of detail, but for those who do science can have no benumbing influence on the esthetic faculties.

Darwin's words have been so often quoted that it would be superfluous to repeat them were it not for the fact that I wish to preach a new sermon on the old text. In 1876 he wrote:

> I have said that in one respect my mind has changed during the last twenty or thirty years. Up to the age of thirty, or beyond it, poetry of many kinds . . . gave me great pleasure and even as a schoolboy I took intense delight in Shakespeare, especially in the historical plays. I have also said that formerly pictures gave me considerable, and music very great delight. But now for many years I can not endure to read a line of poetry: I have tried lately to read Shakespeare, and found it so intolerably dull that it nauseated me. I have also almost lost my taste for pictures or music. Music generally sets me thinking too energetically on what I have been at work on, instead of giving me pleasure. I retain some taste for fine scenery, but it does not cause me the exquisite delight which it formerly did. On the other hand, novels which are works of the imagination, though not of a very high order, have been for years a wonderful relief and pleasure to me. . . .
>
> This curious and lamentable loss of the higher aesthetic tastes is all the odder, as books of history, biographies and travels (Independently of any scientific facts which they may contain), and essays on all sorts of subjects interest me as much as they ever did. My mind seems to have become a kind of machine for grinding general laws out of large collections of facts, but why this should have caused the atrophy of that part of the brain alone, on which the higher tastes depend, I can not conceive. A man with a mind more highly organized or better constituted than mine, would not, I suppose, have thus suffered; and if I had to live my life again, I would have made a rule to read some poetry and listen to some music at least once every week; for perhaps the parts of my brain now atrophied would thus have been kept active through use. The loss of these tastes is a loss of happiness, and may possibly be injurious to the intellect, and more probably to the moral character, by enfeebling the emotional part of our nature.

There may be some question as to whether Darwin did not overestimate his loss. Those who knew him doubted whether there had been any real "atrophy of that part of the brain on which the higher tastes depend." Darwin was perhaps as much mistaken here as he was when he thought that his books might last "a few years."

Thoughtless writers do not stop to inquire whether men who spend their years in business or even in pursuit of the fine arts derive as much pleasure from paintings, music and poetry when they are nearly seventy as when they were twenty-five years of age. They merely quote Darwin's words to show the baneful effect of scientific work on the higher esthetic faculties. Admitting for the sake of argument that Darwin's self-appraisal of his loss of interest in music, painting, poetry and natural scenery may have been correct, a quite different explanation appeals to me as being the more sound. To me the explanation seems to be that Darwin's own great philosophical generalizations overshadowed in esthetic magnificence the poetry and the music and the scenery which gave him pleasure in his youth.

And even if Darwin was wholly right in his evaluation of his "loss of the higher aesthetic tastes" was not his loss the world's gain? Hundreds of millions in each generation may seek to preserve the enjoyment of all their faculties. It is only a great intellectual frontiersman who can give the world a great generalization which has influenced all modern thought.

The Sacrifice of the Frontiersman

It would not be right to close this brief survey of the many frontiers of science

which call for men of vision and determination without emphasizing the fact that the frontiersman of science must encounter great personal hardships and bitter personal disappointments. The frontiersman like the prophet may be without honor in his own country or in his own generation. In science as in geographic exploration it sometimes turns out that the Christopher Columbus is in disfavor while the Amerigo Vespucci gives his name to the Great Discovery.

By way of comparison it is desirable to recall the sacrifices which the pioneer of our west made in exploring and opening to trade and settlement that part of our national domain. Since all that can be done is to illustrate, let us take a few lines from the journal of one whom we may designate as "the unknown frontiersman." In 1827 he found at a trading-post those who could give him information concerning his old companions.

> Here I met again some of the companions who came with me in the first instance from the United States. I enquired about others whom I held in kind remembrance. Some had died by lingering diseases and others by the fatal ball and arrow, so that out of 116 men, who came from the United States in 1824, there were not more than sixteen alive. Most of the fallen were as true men, and as brave as ever fired a rifle, and yet in these remote and foreign parts found not even the benefit of a grave, but left their bodies to be torn by the wild beasts or mangled by the Indians.

Later, as he took passage from Vera Cruz, he wrote with simplicity but with unconscious eloquence of his seven years of failure:

> It would be idle for me to attempt to describe the feelings that welled in my heart, as the sails filled to bear me from the shores of a country, where I had seen and suffered so much. My dreams of success in these parts considered most important by my fellow men, were banished forever. After all my endurance of toil, hunger, thirst and imprisonment, after encountering the fiercest wild beasts in these deserts, and fiercer men, after tracing streams before unmeasured and uncharted by any of my race to their source over rugged and pathless mountains, subject to every species of danger, want and misery for seven years, it seemed hard to be indebted to Charity, however kind and considerate it might be, for the means of returning to my native land.

It is not uncommon to find such expressions of disappointment in those who have been frontiersmen in science. Gregor Mendel, after years of painstaking work, would say hopefully or sadly, "Meine Zeit wird bald kommen." But it did not come until long after the candles burned about the bier of the old abbot. I have already quoted Darwin's words, and while I am not at all sure that he was right in his self-judgment, they at least indicate some of the personal sacrifice which he felt he had made when he found that he had so lost the capacity for relaxation that he felt impelled to write, "My mind seems to have become a kind of machine for grinding general laws out of large collections of facts."

It is needless to multiply illustrations. Kipling has, I think, caught and fittingly expressed the sense of disappointment of the old explorer who heard the whisper, "Something lost behind the Ranges. Lost and waiting for you. Go!" After all his sacrifices and hardships he says:

> Well I know who'll take the credit—
> all the clever chaps that followed—
> Came, a dozen men together—
> never knew my desert fears;
> Tracked me by the camps I'd quitted,
> used the water-holes I'd hollowed,
> They'll go back and do the talking.
> *They'll* be called the Pioneers!
>
> They will find my sites of townships—
> not the cities that I set there.
> They will rediscover rivers—
> not my rivers heard at night.
> By my own old marks and bearings
> they will show me how to get there,
> By the lonely cairns I builded
> they will guide my feet aright.

These words ring true for the scientific frontiersman as for the explorer, for the frontiersman of science is an explorer. The frontiersman of science is

in advance of his time. He must first of all contend with those who say:

> "There's no sense in going further—
> it's the edge of cultivation."

He must often go beyond the ranges without support and under opposition. When he does succeed, it will often have been at a cost of effort which will lead him to look back on the deserts he has crossed and to say with Kipling's "Explorer":

> I remember going crazy.
> I remember that I knew it
> When I heard myself hallooing
> to the funny folk I saw,
> Very full of dreams that desert:
> but my two legs took me through it . . .
> And I used to watch 'em moving
> with the toes all black and raw.

And when he has traversed the great region beyond the foothills, he may have been so much in advance of his time that all the water-holes he hollowed, all the lonely cairns he builded will be forgotten by the clever chaps that follow. They'll be called *the Pioneers.*

All these things must be the lot of the real frontiersman of science. But the vast frontiers of science await—frontiers wider and deeper than any conceived by the geographer of the great era of exploration; frontiers on the exploration of which our future economic, intellectual and social development depends.

The Need for Frontiersmen of Science

If I seem extreme in my views, consider what Lord Curzon had to say twenty-two years ago concerning the influence of geographic frontiers on the development of Anglo-Saxon character. Of the evolution of the character of the American people as conditioned by their westward march across the continent he said:

> In no land and upon no people are the evidences more plainly stamped. Not till the mountains were left behind and the American pioneers began to push across the trackless plains, did America cease to be English and become American. In the forests and on the trails of the Frontier, amid the savagery of conflict, the labour of reclamation and the ardours of the chase, the American nation was born. There that wonderful and virile democracy, imbued with the courage and tenacity of its forefathers, but fired with an eager and passionate exaltation, sprang into being. The panorama of characters and incidents, already becoming ancient history, passes in vivid procession before our eyes. First comes the trapper and the fur-trader tracking his way into the Indian hunting-grounds and the virgin sanctuaries of animal life. Then the backwoodsman clears away the forests and plants his log hut in the clearings. There follow him in swift succession the rancher with his live-stock, the miner with his pick, the farmer with plough and seeds, and finally the urban dweller, the manufacturer and the artisan. On the top of the advancing wave floats a scum of rascality that is ultimately deposited in the mining camps of California and the gambling dens of the Pacific Coast. Scenes of violence and carnage, the noise of firearms, and the bleaching bones of men, mark the advance. The voice of the backwoods-preacher sounds through the tumult in accents of mingled ecstasy and rebuke. But from this tempestuous cauldron of human passion and privation, a new character, earnest, restless, exuberant, self-confident, emerged, here an Andrew Jackson, there an Abraham Lincoln, flamed across the stage; and into this noble heritage of achievement and suffering, the entire nation, purified and united in its search for the Frontier, both of its occupation and its manhood, has proudly entered.

Then turning to the other side of the world, where on a widely different arena but amid kindred travail the British Empire may be seen shaping the British character, while the British character is still building the British Empire, he says:

> There, too, on the manifold Frontiers of dominions, now amid the gaunt highlands of the Indian border, or the eternal snows of the Himalayas, now on the parched sands of Persia or Arabia, now in the equatorial swamps and forests of Africa, in an incessant struggle with nature and man, has been found a corresponding discipline for the men of our stock. Outside of the English Universities no school of character exists to compare with the Frontier; and character is there moulded not by attrition with fellow men in the arts or studies of peace, but in the furnace of responsibility and on the anvil of self-reliance. Along many a thousand miles of remote border are to be found our twentieth-

century Marcher Lords. The breath of the Frontier has entered into their nostrils and infused their being. . . . The Frontier officer takes his life in his hands; for there may await him either the knife of the Pathan fanatic, or the more deadly fevers of the African swamp. But the risk is the last thing of which he takes account. He feels that the honour of his country is in his hands. I am one of those who hold that in this large atmosphere, on the outskirts of Empire, where the machine is relatively impotent and the individual is strong, is to be found an ennobling and invigorating stimulus for our youth, saving them alike from the corroding ease and the morbid excitements of Western civilization. To our ancient Universities, revivified and reinspired, I look to play their part in this national service.

Our western frontier has passed into history. With it has gone one of the forces which developed our national character. For it we must find some equivalent. We have not the wide-flung frontiers of the British Empire. We must make ours the responsibility for other frontiers of our own creation. The wilderness of opportunity lies all about us. Geographically, the world is mapped; biologically, it is largely unexplored. The natural history of plants and animals is partly known; the application of methods of precision to these problems is scarcely begun. Individual branches of science are highly developed; the unification of the sciences is a vision still to be realized. The application of the results of pure science research has transformed our industrial life; more extensive results still await application. Biological resources have been exploited in the past; they must be conserved, developed or replaced through scientific research in the future. Science has contributed enormously to our physical comfort; the scientific method of thought still fails to influence the personal lives of the mass of our citizens. We await only frontiersmen to create the new frontiers beyond the foothills where the trails run out and stop. I venture to think that in the manifold frontiers of science we shall find one of the means of meeting the moral needs of our time.

VEGETATION AND EROSION ON THE EVERGLADE KEYS

By Dr. JOHN K. SMALL
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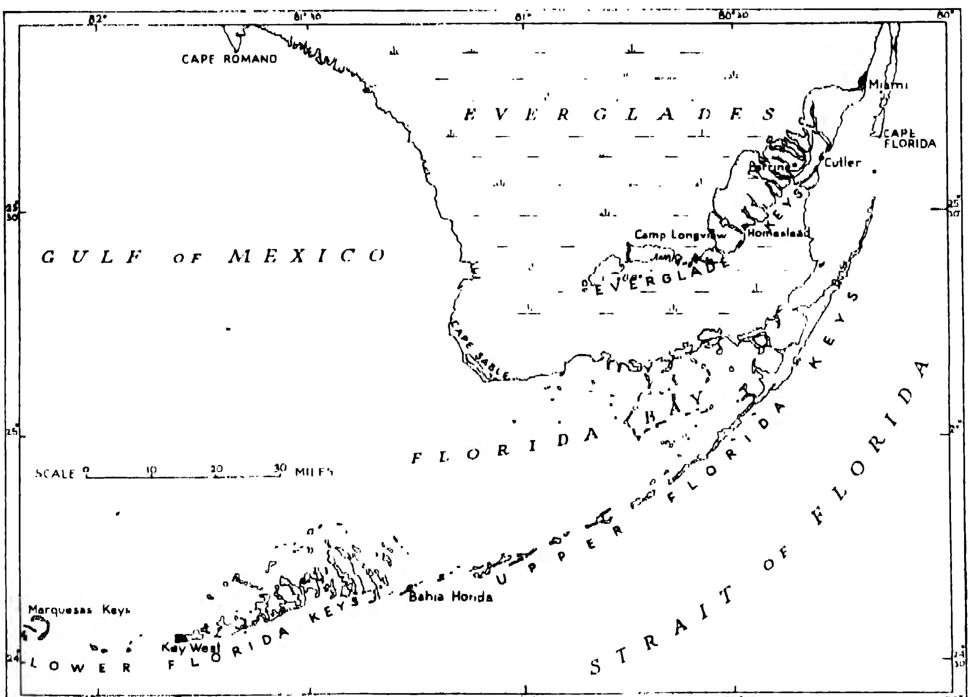
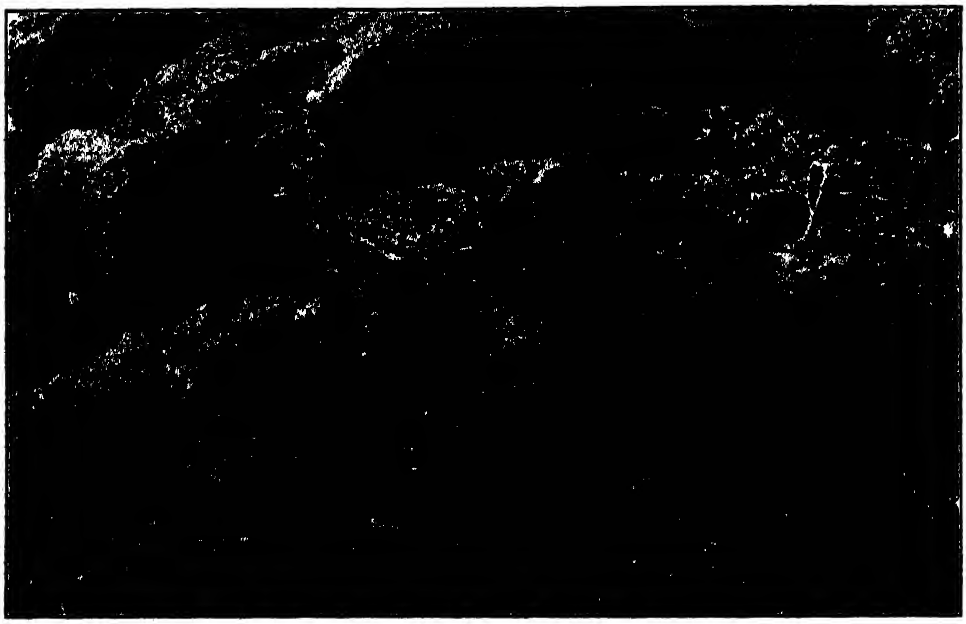
THE traveler in southern Florida meets two strikingly different associations of trees and shrubs. They are the pinewoods and the hammocks.

The pinewoods or pinelands of Florida are nearly level areas of greater or less extent; the high pinelands are dry and often somewhat rolling; the low pinelands where the water-table is always near the surface are often called "flatwoods" because of the flatness of the land. They are composed, according to locality or region, of one or another of the several long-leaf pines. The undergrowth consists of saw-palmetto, shrubs (particularly scrub-oaks), and annual and perennial herbs. They are often fire-swept, and consequently the soil, sand or rock is nearly or quite devoid of humus. As a result of frequent fires and an impoverished soil there is no tall growth aside from the pine-trees, which do not require humus as do broad-leaved trees.

The hammock—the word probably of Indian origin—is a dense growth of mostly broad-leaved trees and shrubs. Sometimes hammock growth occupies a whole circumscribed portion of a geologic formation; at other times it occurs



MAP OF THE SOUTHERN END OF FLORIDA
SHOWING THE LOCATION OF THE EVERGLADE KEYS AND THE FLORIDA KEYS.



EROSION PRODUCED BY MAINLY HUMUS-ACCUMULATION

ON AN ORIGINALLY FLAT SURFACE IN THE SNAPPER CREEK HAMMOCK SOUTH OF MIAMI. THE UNEVEN COMPOSITION OF THE OOLITIC ROCK IS INDICATED BY THE EROSION CAVITIES. THESE CAVITIES IN THE PRESENT-DAY HAMMOCKS ARE MOSTLY EMPTY OR ONLY PARTLY FILLED WITH LIGHT HUMUS WHICH HELPS TO CONTINUE THE EROSION WHICH IS NOW ACTIVE JUST AS IT WAS FORMERLY. THE STRATIFIED CHARACTER OF THE LIMESTONE MAY BE SEEN ON THE SIDES OF THE CAVITIES WHERE THE NUMEROUS STRATA ARE QUITE EVIDENT.

as an island, so to speak, surrounded by pinewoods or prairie. It was formerly confused with the word hummock, a topographic term. Hammocks occur only in regions protected from fire, or in fire-ravaged regions they represent areas that fire has not yet run through. The hammock can not be correlated with altitude or with subsoil, for beneath the humus, resulting from the decaying vegetable matter, may be sand, clay, marl or rock. The use of the word is confined mostly to Florida and adjacent states.

The pinelands predominate in extent of area. The hammocks are infrequent, usually relatively small, and isolated. They are, however, really very significant.

The casual observer sees these associations merely as so many woody plants of diverse characters growing in groups, noticing, of course, the great discrepancy in the relative extent of area of the two main associations. The more careful observer, however, realizing that there must be some reason for the present disproportion of the two associations, seeks to learn if the hammocks have been and are retreating or advancing, and the reasons therefor. The hammock is spontaneously used as the gauge, perhaps because it is the exception. Yet it is also the more prominent feature because of the monotonous landscape furnished by the endless pinewoods. Even the more careful observer, however, may not appreciate the situation fully or grasp the fundamental problems.

What was the tree-covering of that area, now known as the Everglade Keys, at, say, the time man appeared on the

scene? Was it all hammock or was it all pinewoods? Was its arboreous vegetation composed of some ratio of both associations as we find them to-day? In considering this question one must begin with the period following that in which the materials of the Miami oolite had been laid down and cemented together on the bottom of the sea, that is to say, when the islands thus resulting were clothed with their earliest arboreous vegetation. Are the elements of the present herbaceous and woody plant-covering mainly the direct or indirect descendants of this early vegetation?

Of course, the land may have been, then or later, much more elevated above the sea than at the present time. However, such elevation would apparently be of minor importance in the present connection. The general surface of our region could not, in any case, have been much lower, once the forests were established, else the islands would have been submerged by the surrounding salt-water and original vegetation "drowned out." On the other hand, it is certain that the present kind of plant-covering could have existed on a much more elevated plateau, even up to an altitude as high as the available evidence indicates the region once actually attained. Moreover, if, after the existing vegetation had developed, much depression occurred, one would expect to find coastwise or shore plants now isolated in at least some places in the interior where but little elevation now obtains; but such are lacking. It is true that the red-mangrove (*Rhizophora*) and the buttonwood (*Conocarpus*) do grow at a few places rather remote from the present shore-line of the peninsula, but their presence wherever they have been found is easily accounted for otherwise. When and how much the area under consideration was elevated, however, or how much it was depressed, does not, as we have already intimated, complicate the present problem.

Three geologic areas are here involved. These also circumscribe three phytogeographic areas. They are:

I. The upper Florida Keys which are composed of coral-rock and extend from Soldier Key for a distance of about one hundred and twenty miles to the West Summerland or Spanish Harbor Keys. The islands are for the most part greatly elongated and with the long axis in a curve following the general trend of the adjacent mainland. The limestone, mainly an unchanged fossil coral, is named for the largest island, the Key Largo limestone.

II. The lower Florida Keys are a natural group of islands extending from No Name Key and Little Pine Key in a westerly direction for a distance of about forty miles to Key West. The islands of this group are composed of oolitic limestone, and although irregular in shape, the long axis is nearly north and south, thus also differing from those of the previous group. The limestone is technically known as Key West limestone, named for the best-known island of the group.

III. The Everglade Keys or the Miami Limestone Region, an area of exposed oolitic limestone, is the region with which we are directly concerned. It consists of a chain of islands enclosed by the southern portion of the Everglades, except where some of the islands come in contact with the upper part of Bay Biscayne. The chain stretches in crescent form from somewhat north of the Miami River southward towards Cape Sable for a distance of about fifty-five miles. The islands in ancient times apparently formed a part of the Antilles. This was at a time when the subterranean mountain whose summit makes the present peninsula of Florida was less elevated and the islands themselves less eroded. The native vegetation of the islands is essentially of a tropical character, with strong relationships to the flora of Cuba and of the Bahamas. As

EROSION PRODUCED BY HUMUS-ACCUMULATION

ON AN ORIGINALLY FLAT SURFACE NOW IN THE PINELANDS IN THE NORTHERN PART OF MIAMI. THERE TOO (COMPARE FIRST FIGURE) THE UNEVEN COMPOSITION OF THE LIMESTONE IS SHOWN BY THE EROSION CAVITIES. THE RESULTS OF EROSION IN THE PINELANDS IS QUITE SIMILAR TO THAT IN THE HAMMOCKS, AS SEEN IN THE FIRST FIGURE, FOR THE EROSION TOOK PLACE WHEN THE PRESENT PINELANDS WERE HAMMOCK. AFTER THE HAMMOCK WAS DESTROYED THE PINE-TREES REPLACED THE BROAD-LEAVED TREES AND THE CAVITIES WERE GRADUALLY FILLED WITH PIECES OF ROCK AND SAND. THEY ARE THUS USUALLY UNNOTICED UNLESS THE DÉBRIS HAS BEEN REMOVED AS IN THE CASE OF THIS FIGURE. THERE THE STRATIFIED CHARACTER OF THE LIMESTONE IS EVIDENT BY THE NUMEROUS LAYERS.

far as the native flora is concerned the Everglade Keys represent a small tropical area isolated on the mainland of the United States. The Everglades are wet prairie covered with saw-grass (*Mariscus jamaicensis*) and devoid of trees, except where hummocks of soil or rock project high enough above the flood-level to permit trees to exist and thus support hammock or pineland.

The islands are made up of an oolitic limestone called the Miami oolite. This formation extends northward—about fifty miles north of the Miami River—as far as the Palm Beach limestone, but for this distance it is mostly covered with a layer of siliceous sand and humus. On the east the limestone runs out into the Atlantic Ocean as far as the Gulf Stream; on the west it dips under the Everglades, while on the south and southwest it joins with the Lossman's River limestone. The Everglade Keys represent the more elevated portions of this oolite. They are, however, but a fraction of this limestone formation. The keys vary greatly in size, from a small plot to one many square miles in extent. Their latest aerial existence dates from later Pleistocene or early post-Pleistocene times. The formation is probably much older than the Key Largo limestone. It gives evidence of more movement, up and down, than does the latter.

The average elevation of the Everglade

Keys is only a few feet, but it is sufficient to enable the islands to support an almost entirely different flora from that of the contiguous territory. Whatever elevations or depressions took place during Pleistocene or post-Pleistocene times, moreover, the minimum elevation here also was apparently sufficient—in some areas, at least—to maintain a continuous plant-covering.

The Everglade Keys, as they exist to-day, are slightly higher than their environs, either land or water. They have been isolated for a long period of time, during which their general height or that of the aerial parts has been much reduced. Their floristics are unique in Florida. If the southern end of the peninsula was higher at one time, and the present characteristic flora of the Everglade Keys did occupy a greater area than it does now, the eventual subsidence obliterated all traces of the flora beyond its present sharply defined limits.

Consider, first, the most recent rock formation in Florida of an extensive and definite area. This is the Key Largo limestone—a formation built up on a foundation on the Florida reef or Continental Shelf. The Key Largo limestone comprises the upper Florida Keys extending from Soldier Key to Bahia Honda Key and a little further westward along the fronts of several of the oolitic limestone keys. Nowhere else is the Key Largo limestone present. It was evidently the last definite and isolated geological formation in Florida to have been forested. Likewise, it was, perhaps, the latest to be inhabited by primitive man.

Its vegetation is related to that of the younger West Indian islands, whence its ancestors may have been derived. Until the present century, apparently, it had been little changed either by nature or by man. The flora is a simple one, and shows much less variety and less influence from the advent of other floras than its neighboring plant-regions, *viz.*, the lower Florida Keys and the Everglade Keys.

Without exception the islands of the upper Florida Keys are clothed with broad-leaved plants or hammock. Not a native pine-tree grows there. The vegetation has apparently been undisturbed on most of the islands except for modern cultivation and residential purposes and more recent railroad construction and automobile-road building.

Natural forest fires in prehistoric times were apparently very rare. The rapid reforesting and long spells between fires coupled with the somewhat isolated position of the islands have prevented a different character of tree-association from gaining foothold. Nor have recent fires, incident to settling and cultivation, had time to change the woody flora perceptibly, except to deprive it of primeval stateliness.

Even if the upper keys were of relatively recent origin, they would probably have been settled and utilized by some of the aborigines had they possessed an abundance of game and desirable food-plants or areas inviting cultivation. Then their vegetation to-day would have told a different story. As it was, when the white man discovered them these islands were essentially in their primeval condition.

That the flora of the Everglade Keys and the upper Florida Keys had the same origin, or that that of the former was derived, in part at least, from the other, is clear, because the hammock flora of the two regions, particularly the woody elements (the herbaceous elements in the hammocks are rather insignificant), is almost identical. The proportions with regard to area, however, are vastly different. As already stated, the upper Florida Keys support unbroken hammock. The greater portion of the area of the Everglade Keys, on the other hand, is clothed with pine-

EROSION PRODUCED BY ATMOSPHERIC ACTION
AND THE GROWTH OF VEGETATION. THE PICTURE REPRESENTS THE RESULT OF WEATHERING ON A SURFACE, PERPENDICULAR OR HORIZONTAL, OF A MASS OF NON-STRATIFIED OOLITIC LIMESTONE. IN THIS CASE THE OVAL WIND-WORN PARTICLES OF CALCIUM CARBONATE HAVE BEEN CEMENTED TOGETHER INTO AN AMORPHOUS MASS, WHICH OCCASIONALLY CONTAINS FRAGMENTS OF CORALS, PIECES OF SHELLS AND OTHER DÉBRIS. THE EROSION BRINGS OUT THE EXTREME LACK OF UNIFORMITY OF THE DEPOSITED MATERIAL.

woods, and hammock growth is now relatively insignificant in area.

In comparing the vegetation of the two areas under consideration, the question naturally arises as to whether or not the Everglade Keys were once entirely clothed with hammock, as the upper Florida Keys are now. If so, what caused the retreat of the hammocks and the advent of the pinewoods? When and whence did the pine-trees come?

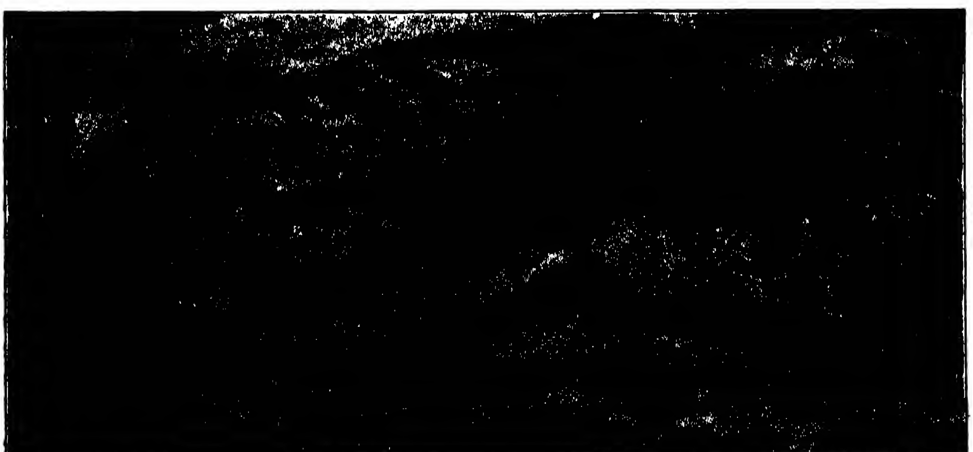
There seems to be little doubt that the Everglade Keys were originally hammock-clad. The circumstantial evidence to support this theory is the present practically undisturbed primeval vegetation of the neighboring and younger geological formation, the upper Florida Keys. The more direct evidence in support of this theory is the type of surface erosion of the rock all over the Everglade Keys. This theory does not apparently appeal to the average superficial observer, for it will appear to him that the erosion in the hammock is quite different from that in the pinewoods.

Let us consider this matter of erosion. In the undisturbed hammocks, as we find them now, is a rock floor covered with loose humus. The carbonic acid and the humus colloids from this decaying vegetable matter which has accumulated for ages, plus rain and capillary moisture and general humidity, have gradually eaten away the softer portions of the limestone. The resulting condition is a copiously honeycombed hammock floor, the cavities varying from the size of a thimble to that of a small house, the depth of the larger holes depending upon the elevation of the hammock floor above the normal water-table. The same condition prevails in the pinewoods. In rare instances is the condition visible, except where the surface débris has been in some way removed, but it does exist everywhere.

In the Miami oolite some parts or areas were composed of nearly pure lime (calcium carbonate). Other areas consisted of a mixture of lime and siliceous sand, and of other matter that was blown or washed in while the limestone formation was being built up. Apparently the major portion of the limestone of the Everglade islands comprises such a mixture. That most of the rock of the pinelands has a large percentage of sand in its make-up has been determined both by analysis and by observation. The disintegration of the limestone is brought about largely through atmospheric or other superficial agencies. First, by the slow but continuous working of the elements; second, by the more rapid action of fire.

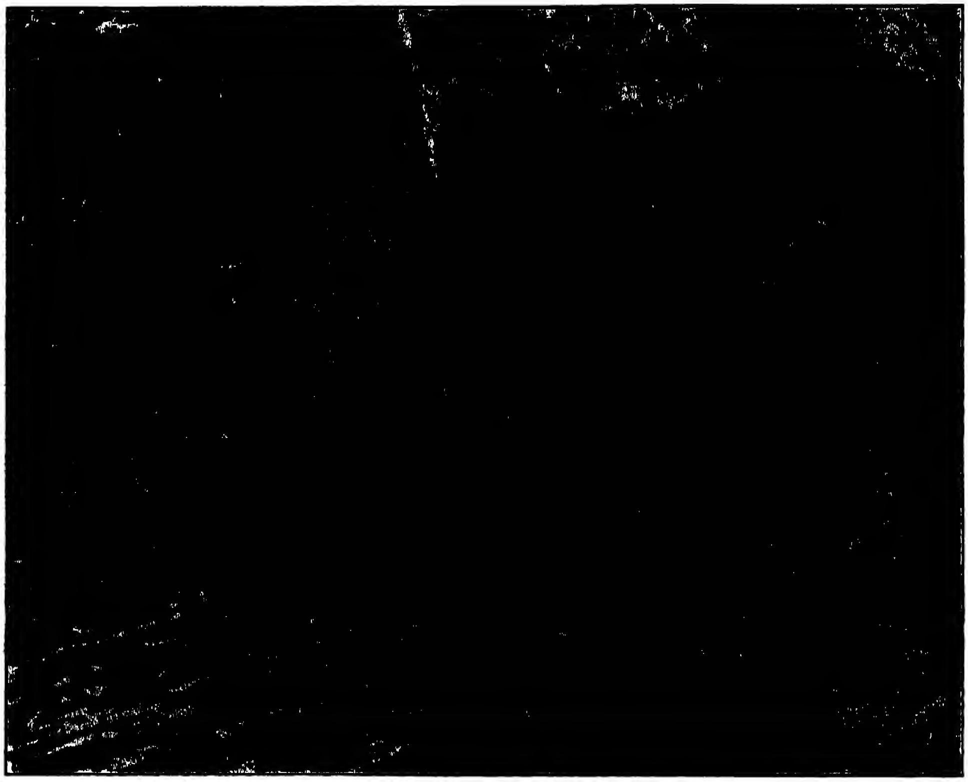
Specimens of quicklime made from the oolite gathered in different areas of the Everglade Keys will give two main results upon slaking after a fire. In the one case, but little residue is left; in the other, more or less sand results. In the pinewoods themselves, after a forest fire, one may find quantities of quicklime, particularly where logs or stumps have been burned causing great heat for a protracted time. Observations on these specimens of quicklime after a rain will show that either the slaked lime leaves behind scarcely any residue or that a quantity of often red sand has been left behind. This red sand mixed with a kind of clay has accumulated in the erosion holes on one of the Everglade Keys to such an extent that the region has been designated "the Redlands district," whence Redlands Post Office, Redlands School, and the "Redlands County" hoped for by some.

But here is the point: If one removes the loose material from the rock floor almost anywhere in the pinewoods, he will disclose a system of erosion holes, or, in other words, a honeycombed surface quite similar to that he finds in the hammocks. In the hammocks the smaller holes are largely filled with loose humus;



EROSION PRODUCED BY WATER

PERCOLATING ALONG THE LESS RESISTANT STRATA. A SECTION OF LIMESTONE FROM ABOUT TEN FEET BELOW THE SURFACE IN THE PINELANDS IN THE NORTHERN PART OF MIAMI AT A POINT ABOUT THREE MILES FROM THE EVERGLADES AND ONE MILE FROM THE SHORE OF BAY BISCAYNE. WHEN THE ARTIFICIAL SECTION WAS MADE, WATER WAS FLOWING RAPIDLY THROUGH THE HORIZONTAL CAVITIES MADE BY THE LEACHING OUT OF THE SOFTER LAYERS OF THE STRATIFIED DEPOSIT OF LIMESTONE. THIS ILLUSTRATES ONE OF THE SUBTERRANEAN OUTLETS OF THE WATERS OF THE EVERGLADES.



EROSION PRODUCED BY ATMOSPHERIC ACTION AND VEGETATION

THE PERPENDICULAR FACE OF A FAULT ALONG BAY BISCAYNE, SHOWING TWO KINDS OF ROCK STRUCTURE: BELOW, WELL-STRATIFIED; ABOVE, NON-STRATIFIED. IN ADDITION, THERE IS A STRIKING UNCONFORMITY WITHIN THE STRATIFIED ROCK. THE DIFFERENCE IN STRUCTURE BETWEEN THE TWO TYPES OF ROCK IS EMPHASIZED BY THE EROSION WHICH HAS TAKEN PLACE.

in the pinewoods the holes are filled with sand and other slowly soluble matter that has come out of a less pure limestone. Furthermore, the rock floor under the sediment in Bay Biscayne shows the same characteristic erosion. This condition is an indication that the land there was, at a former period, more elevated. However, there is a certain difference evident. The surface leaching in the pinelands and under Bay Biscayne was long ago much retarded or essentially stopped, while in the hammock areas it continued. Hence, we find larger erosion holes in the hammocks than elsewhere. A difference in the quantity of erosion is quite noticeable in high hammocks and low hammocks. In the former, where water does not stand, the process of erosion is slower and we find small erosion holes, wells and pits; in the low hammocks when water stands part of the year we find benches, tables, pulpits and urn-like structures. Therefore, the surface erosion of the limestone floor, whether in hammock, in pinewoods or under Bay Biscayne as we find it today, is practically identical.

Reverting now from natural forces, so to speak, and considering those brought to bear by man, generally stated, these forces appeared after geologic disturbances had sufficiently subsided, and favorable meteoric conditions had permitted the land to be forested with the primeval hammock. If the human re-

mains found during the past several years at Vero be authentic, man inhabited the Florida peninsula during the Pleistocene. He appeared, in fact, while decided geologic changes were still in progress. But even then vegetation had doubtless become well fixed on the land, and the wilderness as well as the sea abounded in animal life. There is plenty of circumstantial evidence of this, especially in the coastal regions of the peninsula. The aborigines of Florida and the Caribs of the West Indies doubtless were acquainted with the Florida Keys as well. On the lower Florida Keys, where game also abounded, man left his record. But, as mentioned above, the upper Florida Keys did not offer a hunting-ground for the red man or much vegetation in the way of subsistence, so he passed them by—and their hammocks still remain to show his little interest in those islands.[1]

In its primitive condition, the coastal regions of the peninsula with their lagoons abounding in mollusks and their hammocks copiously stocked with birds and mammals and useful plants, particularly the coontie (*Zamia*), furnished primitive man with all the food he could desire. Then, too, the more tempered climate of the region doubtless attracted him toward the southern end of the peninsula.

A portion of the Everglade Keys—now the Deering hammock at Cutler—has from early historic times been designated on various maps as the Indian hunting-grounds. Perhaps this designation should more properly be assigned to the whole limestone region. At any rate, the whole region, and the Big Cypress Swamp to the westward, was the last stand of the game of the state. Only the recent advent of the white man has caused this part of the state to lose its right to the title of "hunting-grounds."

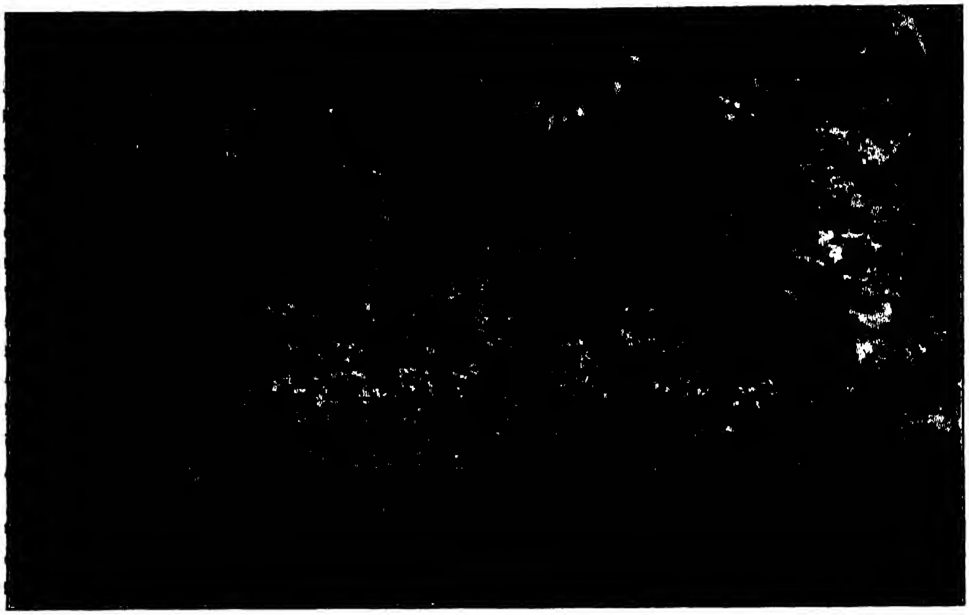
In any case, when the aborigines first occupied the Everglade Keys, they doubtless found them clothed with hammock. Through the mode of life followed by these first inhabitants forest fires were started and were uncontrolled. Later, without doubt, the aborigines purposely set fire to the hammocks in order to drive the game into the open places, thus facilitating their primitive means of hunting game. Fire, in fact, has remained an important and regrettable adjunct of the chase in Florida ever since. The savage white man may sometimes be seen practising it to-day.

Thus large areas of hammock were destroyed. Each fire, we are safe in assuming, pushed the hammock farther back, just as it continues to do to-day. The first fire would destroy most of the humus on the ground, and succeeding fires would make the work of devastation complete.

Moreover, the honeycombed rock, being already burned and weakened by the fire, was exposed to the elements. The limestone that was thoroughly burned was slaked with the first rain. Then the siliceous sand, the unslaked fragments of limestone and other firm materials would fall out. Thus by degrees the honeycombed flood of the one-time hammock lost its character by the breaking down of the edges of the erosion holes and the filling up of the cavities. The process continued until to-day few would suspect that the floor of the pinewoods is to a great extent quite similar to that of the hammocks—often, indeed, it was originally the floor of a hammock—only that its characteristic erosion is hidden from view by the accumulation of débris resulting largely from the effects of repeated fires through a long period of time

The aborigines naturally started fires at different points. One fire after another not only pushed the edge of the

[1] As far as we know, the only evidences of aboriginal occupation on the upper keys are two small Indian mounds near the middle of Key Largo.



EROSION PRODUCED BY ATMOSPHERIC ACTION

COMBINED WITH THE GROWTH OF FERNS AND OTHER PLANTS. THE PERPENDICULAR SIDE OF AN EROSION HOLE IN A HAMMOCK IN THE "HOMESTEAD" DISTRICT. THE EROSION HOLE REPRESENTS A ONE TIME SOFTER LARGE MASS OF LIMESTONE SURROUNDED BY A HARDER MASS WHICH NOW FORMS THE WALLS. HERE THE STRATIFIED PHASE LIES ABOVE THE NON-STRATIFIED ONE (THE REVERSE OF THE NEXT PRECEDING FIGURE) AS BROUGHT BY THE RESULTS OF THE EROSION. THE STRATIFIED ROCK, BOTH BY ITS GROSS AND MINUTE STRUCTURE, YIELDS THE BETTER FOOTHOLD FOR THE GROWTH OF FERNS.

hammock back, but, burning unevenly, a fire or a series of fires finally isolated parts of the hammock growth. Often such isolated bits of hammock persisted. In other words, the condition existing on the Everglade Keys to-day then had its beginning. The fires continued, and in place of a dense broad-leaved forest like that on the upper Florida Keys, clothing the islands, the country became open and often the land was bare. The remaining hammocks naturally tended to reforest the regions, just as they are doing to-day, but the lack of humus would cause a stunted growth and the next fire quickly would obliterate what had been accomplished in the way of reforesting.

But there had been developed plants that were fire-proof, so to speak, just for such regions. The seeds of the Caribbean-pine (*Pinus caribaea*), made to be transported by the wind, blew in from the nearest West Indies and sprouted. The first generation of a single locality may have survived and its descendants spread, or the pine may have started in different places. At any rate, the seedling pine-trees after several years of uninterrupted growth will survive fire, and when a little older they are normally perfectly fire-proof. Thus the pinewoods were developed and have spread as the hammock retreated.

Other plants resistant to fire appeared. Two kinds are particularly abundant and conspicuous in the flora of the pinelands to-day. The coontie (*Zamia*), a cycad, as represented by several species, is exceedingly plentiful. Its stem, a large storage organ, is subterranean and thus safe from fire. *Zamia* is an interesting plant, viewed from any angle.

There is a kind of coontie (*Zamia media*) native in and confined to the hammocks in Florida. It occurs in the hammocks of the Everglade Keys, but it is not plentiful—at least not at the present time. It is one of the few hammock plants with a subterranean storage organ. This makes the plants not only safe from permanent injury, but also prevents the species from being exterminated.

When the hammock areas were ravaged by fire and the plant-association later entirely changed in character, this species may have survived and adapted itself to a wholly new environment, and under the new environment developed into another species, ages later, namely, *Zamia integrifolia*. If this species thus survived, it of necessity adapted itself to an open and exposed environment instead of one of shade and protection; it has changed so far as to thrive on fire! The healthier and more robust plants are those that occupy areas that are periodically fire-swept.

The hammock coontie and the pineland coontie are closely related but distinct. Furthermore, neither shows much variation from a set standard. The characters are constant. The species may be separated not only by characters of the inflorescence, but more readily by character of the leaves—differences evidently brought about directly by the different environments.

DIFFERENTIAL EROSION

IN A LOW AREA IN THE DEERING HAMMOCK, CUTLER. AT A REMOTE TIME THE SOFT ROCK HERE WAS GREATLY IN EXCESS OF THE HARD. THE HARDER ROCK IS NOW REPRESENTED ONLY BY THE OBCONIC CORE. THE TOP OF THE CORE WAS ONCE THE LEVEL OF THE HAMMOCK FLOOR. IN THIS AREA THE STRATUM CONCERNED IS ALL UNSTRATIFIED. NUMEROUS ROCK-VASES, URNS, PULPITS, TABLES, SHELVING, PEDESTALS, CANYONS, CAVES, TUNNELS AND NATURAL BRIDGES OF THIS ORIGIN OCCUR IN THIS AND SIMILAR LOW HAMMOCKS, THE SURFACES SHOWING THIS HIGHLY CHARACTERISTIC ROCK HONEYCOMB OR "FILIGREE-WORK."

EROSION BY THE FLOWING OF AERIAL WATER.

A NATURAL ARCH—BRIDGE—OVER ARCH CREEK NORTH OF MIAMI. THE UPPER PARTS OF THE LIMESTONE HERE HAVE SURVIVED THE AGES—BOTH THE NORMAL FLOW OF THE WATERS OF THE STREAM AND THE PERIODIC FLOOD WATERS—WHILE THE LESS RESISTANT MATERIAL BENEATH HAS BEEN ERODED AWAY. THIS ARCH HAS CARRIED THE COUNTY ROAD, NOW A STATE ROAD, SINCE THE COUNTRY WAS SETTLED BY THE WHITE MAN. IT WAS ALSO USED BY THE ABORIGINAL RED MAN, FOR THERE ARE EVIDENCES OF MUCH ABORIGINAL ACTIVITY THEREABOUTS, IN THE WAY OF KITCHEN-MIDDENS, VILLAGE SITES AND BURIAL-MOUNDS. THE CONCRETE WALLS ON EITHER SIDE OF THE ARCH WERE ADDED IN RECENT YEARS.

The primitive species (*Zamia media*), being a shade-loving plant, has soft tissues, few leaves and large leaflets. On account of its subterranean stem it survived the fire-wrecked hammock-association, but its form and quantity of leafage were not adapted to its new environment. In the pinewoods the plant had about the same moisture supply—capillary water—as it did in the hammock, but in addition it had copious and direct sunlight. So, in order to continue its main function—aside from reproduction—the manufacture and storage of starch, the foliage was readjusted. The leaves were increased in number; the leaflets were divided up with the result of more leaflets with fewer veins each, and the tissues became firmer. And we find a more robust and much more prolific plant and a greater starch-storer than the ancestral species.[2]

The hammock coontie does not grow in commercial quantities, but the natural supply of the pineland coontie has been drawn on both recklessly and indiscriminately for several decades for the manufacture of starch in commercial quantities.

The other low plant particularly prominent in the landscape of the pinewoods is the saw-palmetto (*Serenoa repens*). When and how it originated and whence it came we do not know. However, it is now a typical pineland species, and like the coontie it thrives

[2] The writer has plantations of the two species of *Zamia* in reversed habitats, *i.e.*, the hammock coontie has been planted in the pinewoods and the pineland coontie in the hammocks. The results will be watched with much interest.

on fire. It, too, has a function aside from reproduction in the storage of tannic acid in its stems.

The trunks are typically closely prostrate. When fire-swept the plants show only blackened trunks resembling some large reptilian monsters, with the charred stubs of petioles where the crown once stood. After a short period of rest, however, the bud breaks forth with renewed vigor, develops a fresh crown of leaves and inflorescence and soon all is ready for the next fire. So the process continues.[3]

The saw-palmetto is not now a humus-loving plant, although it may formerly have been one. However, it often does grow luxuriantly around the edges of hammocks where some humus mixed with sand seems to stimulate its growth. Many of the so-called homestead hammocks, southwest of Miami, are encompassed with an almost impenetrable girdle of the saw-palmetto. This girdle plays two important rôles, opposites, but each tending to keep the hammock in *status quo*. First, it confines the hammock. Being so dense it prevents the encompassed shrubs and trees from pushing out into the pinewoods. The shade resulting from the numerous broad leaves of the palmetto does not allow the seedlings of the hammock plants to develop, and in addition, the hammock growth adjacent to the palmettos is usually relatively weak and it often keeps at a distance.

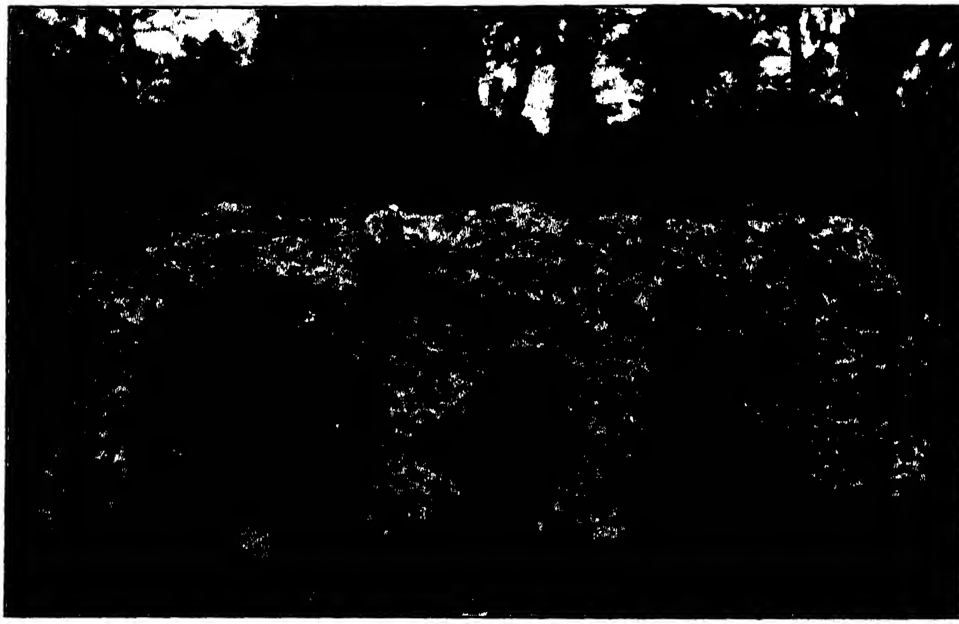
Second, the palmetto girdle acts as a fire-break. When the fire in the pine-woods meets the palm cordon, it spends itself, and seldom, unless the natural growth is weak or has been interrupted or otherwise destroyed, eats its way into the hammock. If, however, the fire does break through and burns part of the hammock vegetation and humus, succeeding fires will probably continue the destruction by burning away weak and tinder-like vegetation that may have replaced that formerly burned. Then the pine-trees will spring up, and that much more pineland is added to the region.

Incidentally, the tangled mass of prostrate, floundering and interlaced saw-palmetto trunks furnishes a favorite lair of the diamond-back rattlesnake which can thus prey either on the animals of the hammock or on those of the pine-woods, according to his particular desire or luck.

Thus the hammocks of the Everglade Keys have been crowded back and gradually reduced in size, and then confined. Their flora is not extensive. It comprises mostly woody plants, almost without exception tropical types. There are few herbaceous plants—mostly vines that can climb in the trees and thus get sunlight, smaller plants that can live in humus, epiphytic ferns, bromeliads and orchids and a variety of lower flowerless plants. The herbaceous elements are mostly shade-loving kinds, nearly all of which perish with the first fire. Their whole vegetable make-up is typically that of insular tropical America.

The pinelands, on the other hand, as they gradually increased in size, received

[3] There are many interesting features connected with the "fire-proof" plants. The general results of fire on vegetation are destructive. However, the results are sometimes not wholly negative. For example, the stem of *Zamia* is normally simple and with a single terminal bud. In the pinelands the irritating effects of repeated fires cause a stem to produce additional buds which represent branches. Plants with as many as twelve buds or branches may be found. Thus the yield of foliage and fruit of a plant may be increased twelvefold. Likewise, the saw-palmetto, as in the case of most palms normally, has but a terminal bud. Through repeated irritations by fire an old prostrate stem—trunk—will often send out numerous branches from the spent leaf-axils. Thus, again, the foliage and fruit yield may be materially increased. Even the erect silver-palm may sometimes be found with numerous lateral branches as a result of the irritating effect of fire.



GROTESQUE EROSION

IN A HAMMOCK NEAR MIAMI. HERE THE ONE-TIME GROUND LEVEL OR HAMMOCK FLOOR AND THE ONE OR TWO FEET OF UNDERLYING ROCK HAVE MOSTLY DISAPPEARED. THIS TABLE OF PARTICULARLY HARD PORTION OF THE ROCK, ALTHOUGH OF RATHER EVEN HARDNESS ON TOP, HAD SOFTER PARTS BENEATH AS IS SHOWN BY THE NATURAL-BRIDGE OR TUNNEL MANNER OF EROSION. THE ORIGINAL DEPOSIT HERE WAS UNSTRATIFIED AND LIKE MOST OF THE LIMESTONE OF THE EVERGLADE KEYS THE MATERIAL WAS OF EOLIAN ORIGIN.

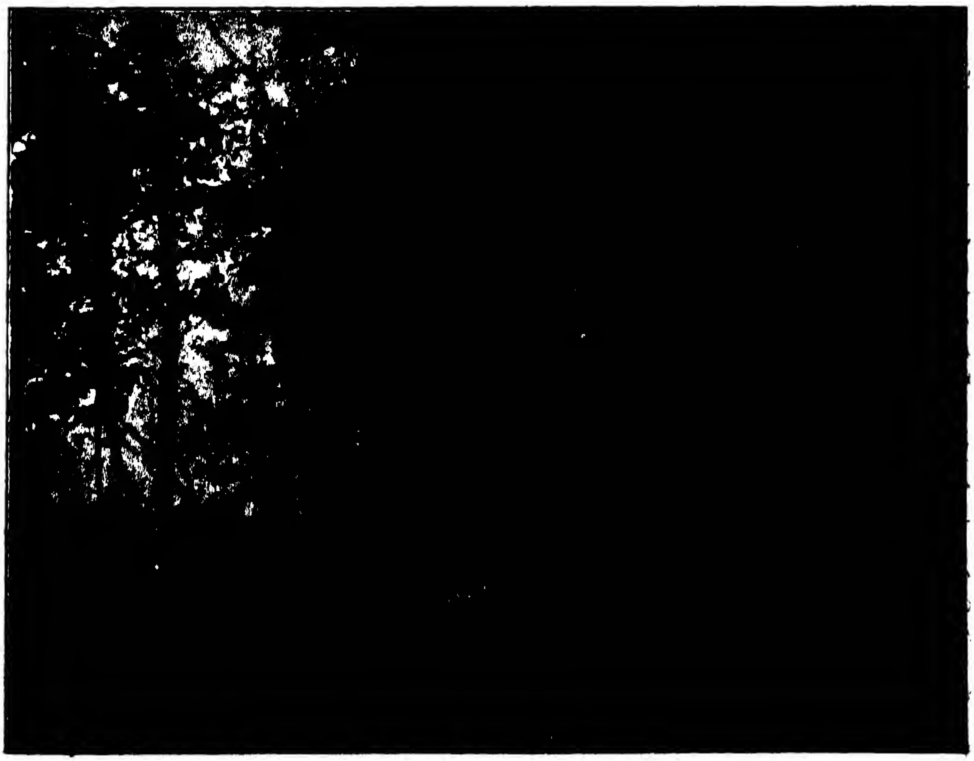
exotic elements into their flora, as well as developing endemic forms. In addition, they have retained many of the hammock plants, but these only in dwarfed, stunted and deformed conditions. Elements of the pineland flora have been derived from the West Indies on the south and from continental North America on the north. Herbaceous plants, not humus-lovers as in the hammock, are abundant. There are annuals that maintain themselves in spite of the frequent fires by dropping their seeds in the sand and in the rock cavities. There are perennials that resist the fire by large woody roots and rootstocks or by buried specialized storage organs, like those of the coontie and the saw-palmetto.

The present endemics are either the sole survivors of plants once more widely distributed geographically or forms that have developed locally as a result of the peculiar environment of the region, just as the coontie above referred to apparently came to be.

Each of these elements of the pineland flora is extremely interesting. However, they are not more so than the various hammock shrubs and trees struggling for existence in the pinelands. Although deprived of humus, the descendants of large forest trees of the former hammock are maintaining themselves in the pinelands, but they are mere pygmies as compared with their ancestors and hammock brethren. Forest trees that commonly grow to a height of over fifty feet in the hammocks may be found within a stone's throw in the adjacent

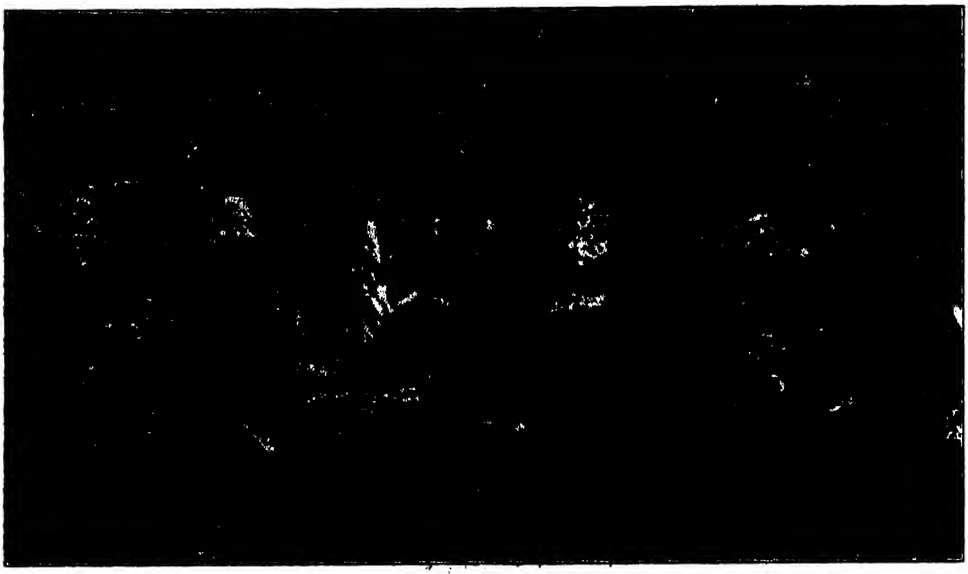
pinewoods less than six inches tall, and full-grown trees at that. The trunks often do not rise above the rocky floor. Cringing from fear of fire, as it were, these forest pygmies develop their trunks wholly within the erosion holes formerly leached out of the limestone when hammock clothed the region instead of pinewoods, and pass their existence thus, sending out only a few leafy branches in order to carry on their necessary life-processes. These "tree-trunks" are so firmly imbedded in the rock that in order to dislodge them the rock must be broken with a sledge-hammer or split with an axe!

The areas of pinewoods apparently situated near the centers of ancient civilization—and corresponding closely to those more recently devastated by modern civilization—have had these plant relics of the former hammocks more thoroughly obliterated. In the more remote parts, which have naturally been less frequently subjected to fire, we find a more copious growth of this abnormally developed hammock vegetation than elsewhere. In a few places real broad-leaved



EROSION BY ATTRITION

THE LAPPING OF SMALL WAVES ON A CLIFF, THE FACE OF A FAULT, FRONTING BAY BISCAYNE. THE ONE-TIME SHORE-LINE AT THE BASE OF THE CLIFF, NOW SLIGHTLY ELEVATED, IS INDICATED BY THE CONCAVITY FORMERLY SCOURED OUT OF THE LOWER HALF OF THE CLIFF BY THE ACTION OF THE WAVES. NEARBY THERE IS ANOTHER EXAMPLE OF EROSION BY ATTRITION OR ABRASION. THIS IS THE CELEBRATED PUNCH-BOWL, A CIRCULAR WELL, BORED IN THE USUAL MANNER OF POT-HOLES, WHEN THE SHORE-LINE WAS SLIGHTLY LOWER. THE WELL CONTAINS FRESH—SURFACE—WATER, BUT THE BOTTOM STANDS AT SUCH A LEVEL THAT THE WATER RISES AND FALLS WITH THE TIDE.



DIFFERENTIAL EROSION

IN A LOW PART OF THE DEERING HAMMOCK AT CUTLER. AT THIS SPOT THERE WAS FORMERLY MORE HARD THAN SOFT ROCK. THIS PART OF THE HAMMOCK HAS FOR AGES BEEN SUBMERGED UP TO THE TOP OF THE ROCK-TABLES ONE, OR EVEN MORE TIMES, A YEAR. AT THE PRESENT TIME, AS FORMERLY, THE MAXIMUM HEIGHT HAVING BEEN REACHED, THE WATER RAPIDLY SUBSIDES FOR A TIME. SOONER OR LATER THE MORE RAPID SUBSIDENCE IS CHECKED, *i.e.*, THE LOWER THE WATER, THE SLOWER THE SUBSIDENCE, HENCE THE GREATER EROSION NEAR THE BASE OF THE WALLS OR SIDES OF THE TABLES, FOR THE EROSIVE AGENTS ARE MORE CONCENTRATED AND HAVE A LONGER TIME TO ACT ON THE ROCK.

trees have sprung up and have maintained themselves in spite of the fires, because there is never much tinder developed about them; but even here they have not yet succeeded in reproducing themselves in such numbers that any association approaching a hammock has developed.

It is not possible to calculate or even imagine the ratio of elevation lost through subsequent subsidence and erosion. However, erosion has been prolonged and extensive. It has been both aerial and subterranean, mechanical and chemical. Mechanical erosion has operated through flowing water on the surface, by subterranean flowing water and by the action of the waves on the shoreline. Chemical erosion has been more extensive. Rain-water charged with carbonic acid and later laden with the acids of decaying vegetable matter may either stand on the rock floor or percolate through rock by gravity or later rise as capillary water. Through all these agencies of reduction the limestone gradually gives way.

To summarize: The evidence furnished by the character of the surface erosion similar in both the hammocks and the pinelands shows that the ancient islands, now the Everglade Keys, were formerly hammock-clad. That they were formerly more elevated is evidenced by the rock floor of Bay Biscayne showing the same character of erosion as that of the present hammocks and pinelands. The fact of this one-time elevation is also established by the present existence

of subaqueous caverns in the limestone, with immense stalactites which must have been formed above the water-table.

The foregoing geologic history and the present geographic position of the Everglade Keys have conspired to produce an area surpassing in uniqueness anything within the continental United States. Situated on the end of a peninsula extending far into a tropic sea, they have received a predominance of tropical flora, and this mingling with such northern plants as have come down from the temperate mainland, an association is formed of opposing types yet living together in a habitat which has called for their utmost efforts for survival, for the solid rock floor has caused even the trees to spread their roots on its surface, as they can not penetrate it, thus becoming epipetrinous, or plants living on the rock rather than in the soil.

CASTLE PEAK

Standing some three hundred feet above the surrounding country, is a prominent landmark, visible from the Texas and Pacific Railway trains some miles away. It marks the locality where are to be found the ancient trails of animals which lived long before the birds and mammals.

ANCIENT TRAILS IN THE VALLEY OF THE CLEAR FORK, TEXAS[1]

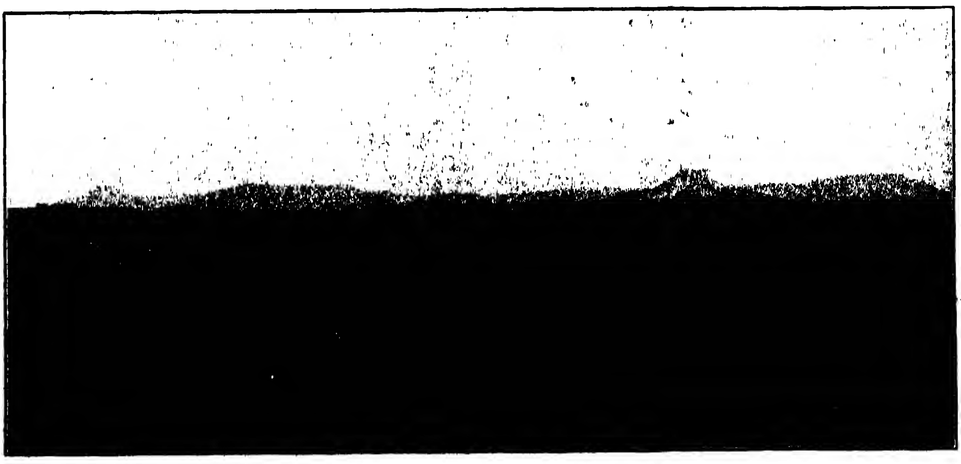
By Professor ROY L. MOODIE

SANTA MONICA, CALIFORNIA

THE observing traveler sees many different kinds of trails. Winding over the sage-covered hills of western Wyoming he may see the wide trail of the forty-niners, where ox-teams, dragging heavy wagons, went four abreast. They wore down the sage brush so completely that the overland trail is still plain, after half a century of disuse. At places in western Kansas deep ruts of the old Santa Fé Trail are preserved. Man-made trails are everywhere. Hunters follow the trails of game. But the trails we went to Texas to see were none of these. They were the trails of early land creatures which lived during the time, geologically ancient, when the trail-makers themselves were the highest types of four-footed creatures in existence.

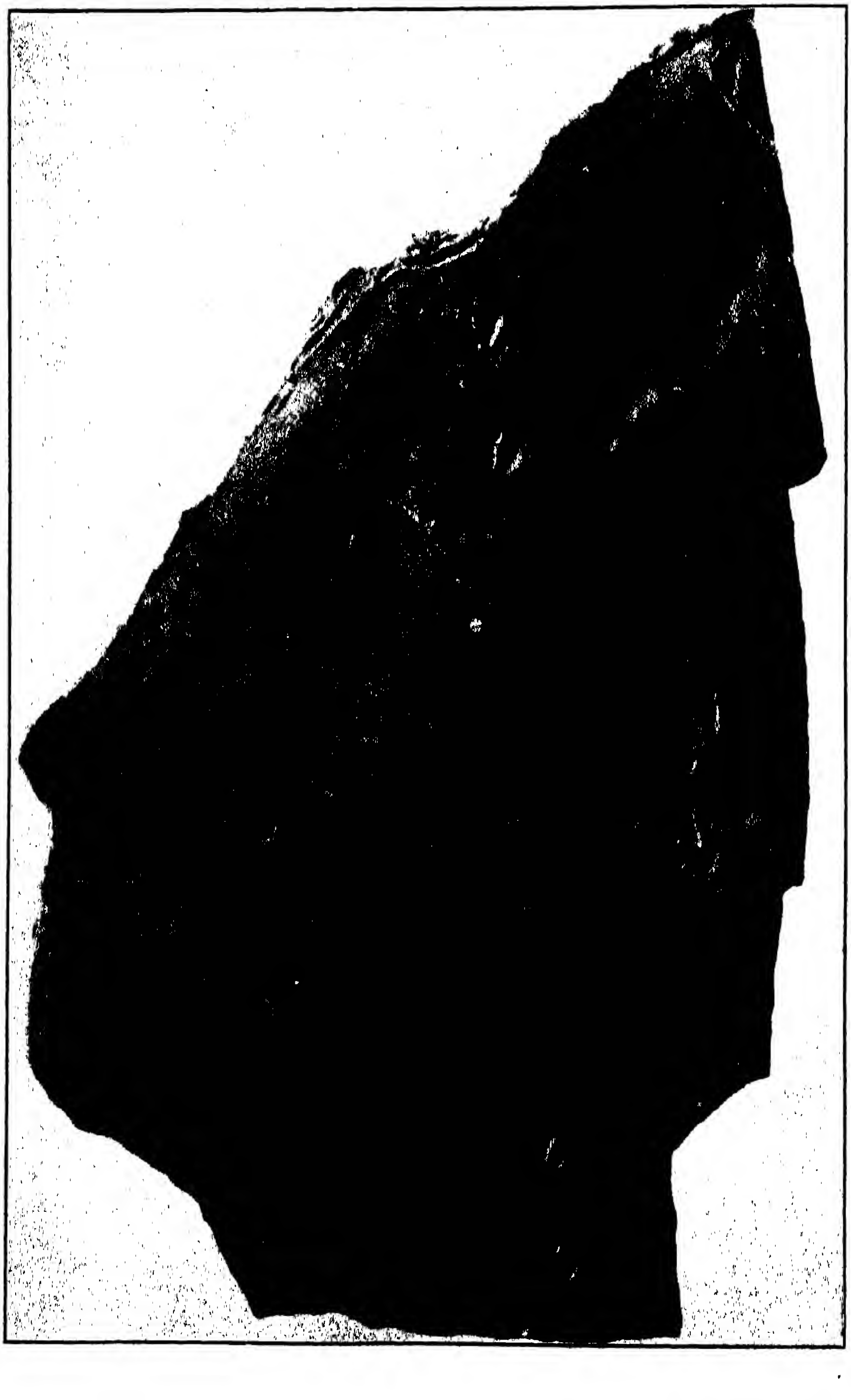
When they were making their tracks on the soft red mud the ancient Paleozoic period was drawing to its close. The time was after the closing of the great Coal Period, during the era which geologists call the Permian Age. The Permian rocks, the world over, are red, often a brilliant red, indicating, so ge-

[1] Photographs by Thomas L. Miller, San Diego.



THE VALLEY OF THE CLEAR FORK

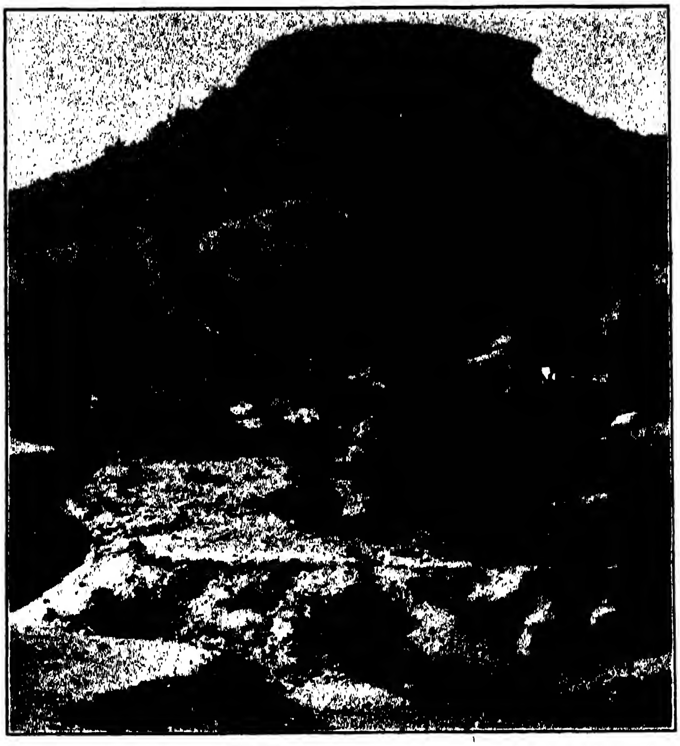
A TRIBUTARY TO THE BRAZOS RIVER, IN ITS UPPER REACHES IS MILES WIDE BETWEEN ITS LOW TABLE-LANDS, FORMING A WELL-POPULATED AGRICULTURAL DISTRICT IN THE NORTHERN PART OF TAYLOR COUNTY, TEXAS. THE DRAINAGE IS TO THE NORTH AND EAST. TWO BUTTES, OUTLIERS FROM THE MASSIVE, LIMESTONE-CAPPED MESA, ARE PROMINENT, EXPOSING AT THEIR BASES BITS OF ANCIENT GEOGRAPHY. THE BUTTE TO THE RIGHT IS CASTLE PEAK, AT WHOSE NORTHERN BASE ARE FOUND THE REMNANTS OF THE ANCIENT, SHALLOW POND WITH WIDE, FLAT, MUDDY SHORES, CRISSCROSSED WITH MANY KINDS OF TRAILS AND STILL SHOWING ITS DEEP, MULTITUDINOUS SUN- OR MUD-CRACKS, RIPPLE-MARKS, RAINDROPS AND OTHER WEATHER MARKINGS. AS THE VALLEY CONTINUES TO WIDEN BITS OF ANCIENT GEOGRAPHICAL CONDITIONS ARE EXPOSED WHICH MUST BE INTERPRETED FROM THE FRAGMENTS OF TOPOGRAPHY REMAINING. THE OBSERVER SEES THIS VIEW FROM THE ROAD TO MERKEL, LOOKING TOWARD THE SOUTH AND EAST.



About natural size.

ONE OF THE OLDEST OF ALL KNOWN FOUR-FOOTED ANIMAL TRAILS

FOUND IN THE SHALES ON THE NORTH SLOPE OF CASTLE PEAK, TEXAS. THE ANIMAL MAKING THE TRAIL WAS A SMALL REPTILE-LIKE AMPHIBIAN, ABOUT TEN TO TWELVE INCHES LONG, WHICH LIVED DURING THE PERMIAN AGE, MILLIONS OF YEARS AGO.

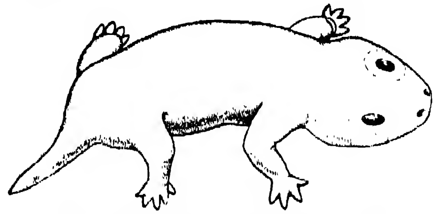


THE SLOPE OF CASTLE PEAK

TYPIFIES IN ITS DRAINAGE THE WATERSHED OF THE VALLEY. DRAINAGE BEGINNING NEAR THE TOP OF THE PEAK FLOWS NORTH AND EAST, BEING JOINED AT THE FOOT OF THE PEAK BY STEEP-WALLED GULCHES OR SMALL CANYONS WHOSE SLOPES WERE COVERED, ALMOST IN SHINGLE FASHION, BY FOOTPRINT-BEARING PLATES. THE MOST PROLIFIC LAYER IS EXPOSED AT THE TOP OF A GULCH COMING IN FROM THE WEST, JOINING THE DRAINAGE OF THE PEAK AT ITS NORTHERN BASE. ALTHOUGH "FROG-TRACKS," AS THE FOOTPRINTS ARE CALLED LOCALLY, HAVE BEEN COLLECTED AT CASTLE PEAK FOR MORE THAN THIRTY YEARS, YET IT IS PROBABLE THAT AT THE PRESENT RATE OF EROSION TRACKS WILL BE FOUND THERE FOR ANOTHER CENTURY.

ologists tell us, that arid conditions prevailed. Desert conditions were common. Animals to survive must be of sturdy stock. In many favorable nooks, here and there, animal and plant remains have been found, and in such a nook we found the "ancient trails," brought to the surface by erosion after having been preserved by overlying rocks for millions of years. The locality has been known for more than a quarter of a century and a few small collections have been made, but nothing of note has been published regarding the nature of these "ancient trails." We have only the trails to study. The animals themselves are unknown.

An attempt is made to reconstruct an ancient bit of geography in the land now situated in Taylor County, Texas. We



THE ANCIENT TRAIL-MAKER

WAS NOT UNLIKE THE SMALL CREATURE SHOWN ABOVE, EXCEPT THAT IT HAD SHARPER TOES.

THE LEDGE OF SHALE

ABOUT TWELVE INCHES IN THICKNESS, IS CUT UP INTO IRREGULAR PENTAGONAL COLUMNS BY ANCIENT SUN-CRACKS WHICH FORM THE VERTICAL JOINT PLANES. ON SEPARATING THE LAYERS ONE OFTEN FINDS "ANCIENT TRAILS" AT FIVE OR MORE LEVELS, INDICATING THAT SUCCESSIVE LAYERS OF MUD WERE WASHED IN AFTER THE LAYER ALREADY DEPOSITED HAD DRIED OUT A LITTLE. IT SEEMS PROBABLE THAT THIS ENTIRE BED OF MUD-SHALE WAS FORMED DURING AN EXCEPTIONAL RAINY SEASON IN A SHALLOW POND OR MUD LAKE WHICH WAS SUBJECTED TO SUCCESSIVE FLOODINGS FROM ADJACENT STEEP SLOPES.

have the records of the winds, the rains, the slow drizzles, the ripple marks, the sun-cracks and the many crisscrossing trails. Plants were very rare and of the type of the scouring rush. These things we must interpret into geographical conditions of the long ago.

Birds and mammals did not exist during the Permian, and the amphibians and reptiles were voiceless. If we could have stood near the edge of this mud flat where the creatures left their trails the sounds we could hear would be few. The winds rustled in the rough-coated rushes. There might be shrill pipings of insects. Thunder-storms may rarely have been heard, and the splash of the rain seldom. Rocks may have clattered on the hills, but of the noises which we hear now there were none. The sunshine was doubtless brilliant, and seldom veiled by clouds. At the foot of a nearby steep range of hills, the rare rains had piled up the heavier detritus carrying red clay in suspension to be deposited on the mud flat after the low gradient had slowed down the currents to a slow oozing of the liquid mud. As the slow ooze moved forward footprints made on the flat would be gently filled and covered by the layer of red mud which was later, by pressure, converted into shale—the thin bedded shale which preserved the footprints.

Castle Peak to-day marks the place where the preceding events took place. It is a fitting monument for the ancient records of former happenings. It marks the place of the fossil hunters' paradise, where ancient relics by the thousand may be secured with a minimum of effort, for most fossil hunters, like other folks, are lazy when there is no need to work. The fossil beds occur on the prop-

erty of pleasant-mannered, agreeable people. All the collector needs to do is to select what he wants, carry several armfuls of track-bearing slabs to the nearest shade and pack them away. Nowhere else in the world does such a pleasing combination exist. No other locality of limited extent yields such remarkable "ancient trails," and nowhere have such tracks been found. The steep slopes of the peak recall similar conditions in ancient times when erosion by sun and rain supplied the red sediment for the pond or small lake on whose wide shores ancient animals walked and crawled. Insects walked for short distances and took flight. Thousand-legged worms left their trails everywhere. Worms left their burrows and the four-footed creatures their tracks, but all went elsewhere to leave their remains to be fossilized, and nothing but tracks remains. In the dark belt of juniper, encircling the base of the peak, attractive camping places are found. Castle Peak is a locally famous picnic resort. Man-made trails wind in and out of the chaparral, to and beyond the bed of fossil trails. Oyster shells of Cretaceous Age have weathered out in abundance from the massive capping layer of limestone forming the beak of the butte.

Lizard-like reptiles made some of the trails. They were quick and nimble, adapted for land travel, without webbed feet. Their claws were sharp, and at places where the mud was partly dry these little reptiles left only their claw prints, sharply marked and easily recognized. Ancient salamanders, with webbed feet, ventured from the shallow pool to leave a few characteristic foot-

THE "COLUMNS" OF SHALE BREAK LOOSE

BEING UNDERMINED BY THE WEARING AWAY OF THE SUBJACENT RED CLAY, AND THE PLATES SEPARATE READILY AND SLITHER DOWN THE SLOPE, SHINGLE FASHION. THE SUN LOOSENS THE FREE INTERCALATED DUST WHICH THE WIND BLOWS AWAY OR IT IS WASHED OFF BY THE RAIN, THUS EXPOSING THE "TRAILS" ON THE SLABS. ON ACCOUNT OF THESE CONDITIONS IT IS DIFFICULT TO FOLLOW A GIVEN TRAIL FOR ANY DISTANCE OR FROM COLUMN TO COLUMN. WE READ THE RECORDS ON THE CROSS-SECTIONS OF THE SHALE COLUMNS WHICH FORM ONLY A PART OF THE EVIDENCE. THE DARK AREAS ON THE PLATES IN THE PICTURE ARE A DEEP RED. THE LIGHT MOTTLINGS AND EDGES OF LIGHTER COLOR ARE PALE GREEN OR GRAY.

THE PIECES OF SHALE

ON THE SLOPES OF "TRAIL GULCH" BORE MANY FOOTPRINTS OR WEATHER MARKINGS FROM WHICH WE HAVE READ THE STORY OF THIS FAR-OFF TIME. THE FOOTPRINTS WERE TRAILS OF FOUR-LEGGED ANIMALS, REPTILES AND AMPHIBIANS, OF INSECTS, OF CENTIPEDES, BURROWS OF WORMS AND OTHER TRAILS OF A DOUBTFUL NATURE. THE WEATHER MARKINGS TOOK THE FORM OF RAINDROPS, SUN-CRACKS, DRIZZLE RUN-OFF, WIND MARKINGS AND LOW, BROAD RIPPLE MARKS. WITH A SMALL BRUSH ON SOME OF THE PIECES, NOT CLEANED BY RECENT RAINS, ONE COULD EXPOSE INTERESTING EVIDENCES OF ANCIENT HAPPENINGS. AS THE SUN WENT TOWARD THE WEST CASTING SHARP SHADOWS ONE MIGHT SEE SMALL FOOTPRINTS ON SLABS MANY YARDS AWAY. THIS IS THE FOSSIL HUNTER'S PARADISE, WHERE WITH SCARCELY AN EFFORT WONDERFUL SPECIMENS COULD BE OBTAINED.

prints, entirely different from those of the aggressive reptiles. Long-legged, two- and three-toed reptiles, otherwise unknown, left their tracks in the soft mud. Two-toed animals are not otherwise known to have existed during the Permian.

Accompanying the four-footed creatures and doubtless serving as their food were sharp-shinned insects, leaving a clearly marked trail. Centipedes and their relatives, the millipeds or thousand-legged worms, scurried across the mud, often getting into difficulties in the soft ooze. Soft-bodied worms left their tubes. The surface mud was so fine and soft that many minute trails appear, suggesting a world of life otherwise unknown. Tiny tracks offer tantalizing subjects for speculation.

While the drainage from Castle Peak to-day is toward the north and east it seems probable that in Permian times the highlands were toward the west and the drainage was toward the east and south. The pond or small lake existed only during the wet season, and for only a limited time. This shallow body of water lay near where now is the northern foot of Castle Peak. The mud flat where the footprints were made lay between the pond and the foot of the hills which furnished the sediment.

The sun shone hotly on the exposed

THE THIN SHADE OF THE JUNIPER

GAVE WELCOME RELIEF FROM THE HOT MID-SEPTEMBER SUN IN THE TRAIL GULCH DURING THE PACKING OF THE COLLECTION. EACH SHALY PLATE WAS WRAPPED IN A HEAVY NEWSPAPER COAT AND TIED, THEN PACKED WITH OTHERS IN A PAPER CARTON. ON REACHING TOWN ALL CARTONS WERE CAREFULLY PACKED INTO A WOODEN SHIPPING CASE TO PROTECT THE THIN PLATES FROM BREAKAGE.

mud flat and huge sun-cracks developed, so deep that they cut through all the layers of mud and so wide that they are still evident, cutting through the entire bed, converting the shale into columns of an irregular pentagonal shape. With the drying up of this small area the animals went elsewhere to seek their food—possibly to an adjacent pool near whose borders they continued their brief span of life, leaving their bodily remains no one knows where.

More than a dozen species of footprints have been recognized, representing two types of primitive amphibians, and ancient reptiles. The technical details will be published elsewhere. One easily characterized species, originally described from the Grand Canyon of Arizona, is found in the Castle Peak beds; all the others are new to the sci-

Photograph by Dr. F. C. Clark.

TRACKS OF A SEA-GULL

ON RECENT MUD IN SANTA MONICA, SHOWING HOW SUN (OR MUD) CRACKS FORM. THE TRACK IN THE MIDDLE HAS ONE CLAW MARK MOVED BY THE CRACK.

THE MARGINS OF THE ANCIENT POND

AND ASSOCIATED MUD FLAT ARE MARKED IN THE ROCKS BY THE "PINCHING OUT" OF THE SHALE LAYER. AT THE PHOTOGRAPHER'S HAND THE LEDGE HAS BECOME VERY THIN, AND IT GAVE OUT ENTIRELY A FEW FEET FARTHER TO THE RIGHT. FOOTPRINTS WERE RARE HERE BECAUSE THE MARGINS OF THE MUD-FLAT WERE DRIER AND DID NOT SHOW OR TAKE MARKINGS SO READILY AS THE SOFTER AREAS.

ence of ichnology, as the study of fossil footprints is called.

My first acquaintance with the Castle Peak fauna was when my good friend, Dr. F. C. Clark, of Santa Monica, California, showed me a collection of footprints from those beds in Texas which have become known as the Castle Peak beds. Our trip to the deposit was made possible through aid from the department of geology and paleontology of the University of Chicago, and from the Los Angeles Museum. The trip involved an auto ride of nearly three thousand miles, which was made safely. The fossilized "ancient trails" will still yield new facts to further study, and it is our hope to go again to Castle Peak to search out further evidences of these very ancient "trail-makers."

THE ELIMINATION OF THE MALE SEX IN THE EVOLUTION OF SOME LOWER ANIMALS

By Dr. ARTHUR M. BANTA

CARNEGIE INSTITUTION, COLD SPRING HARBOR, N. Y.

SEX and sexual reproduction appear almost as essential and fundamental in the plant and animal world—both with the simpler and higher forms of life—as nutrition and respiration. Sex and its differentiations are indeed some of the most useful characters for the study of the course of evolution. In some groups of living organisms, *e.g.*, certain insect and crustacean groups, the peak of differentiation apparently lies in the highly specialized secondary sexual characters.

Every one appreciates the fact that the term sex implies two sexes, the female and the male, and that the two sexes in the higher forms differ profoundly not only in the germ glands, but in secondary sex structure, in physiological characters, even in psychological and behavior characteristics. The writer wishes to point out in this brief paper a fact which is perhaps less appreciated—namely, that in certain groups of animals, particularly with the Cladocera (with which he has some familiarity) the male sex has in the course of evolution assumed less and less importance until now one can definitely point out that in certain forms the male is apparently in course of elimination—this sex has indeed been quite eliminated in a few Cladocera—and that *this elimination has actually proved advantageous to the forms involved.*

THE ANCESTRAL TYPE

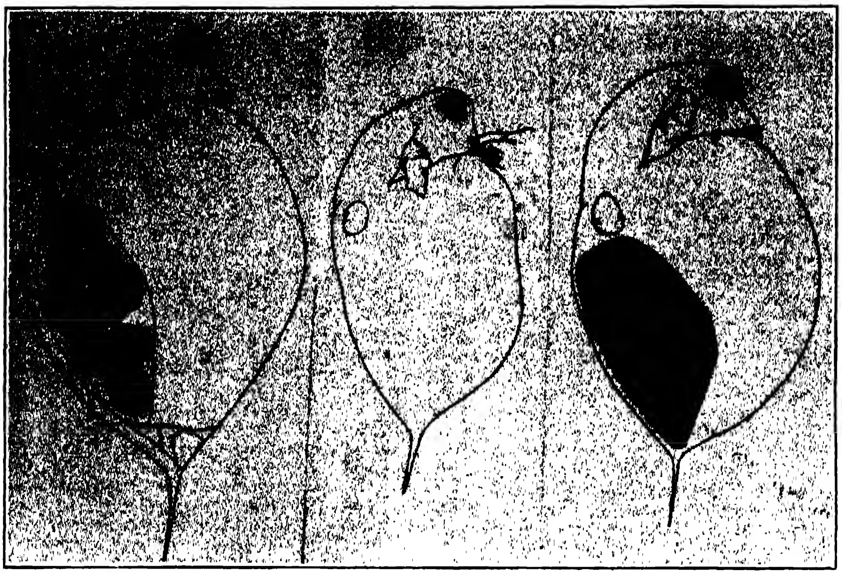
Cladocera are a group of the lower crustaceans and hence may be thought of as cousins of the lobster and shrimp. They are popularly known as "water-fleas," although they are quite innocent of any real relation in structure or behavior with their unpopular namesake. These small animals live in fresh-water lakes, ponds and puddles the world over. From analogy with other organisms, we must believe that their ancestral form, like most plants and animals of to-day, reproduced entirely by sexual reproduction (Fig. 2 A). At the present time, however, no Cladocera forms are known in which sexual reproduction is the exclusive means of reproduction. Indeed, we shall see that sexual reproduction has assumed a very minor rôle in many of these forms and that it, together with the male sex, has been entirely dispensed with in some forms.

THE LIFE HISTORY OF A DAPHNIA; THE INTERMEDIATE TYPE

A few details of the life history of these animals may perhaps prove of interest and be useful in presenting the striking situation the writer wishes to portray. Many present-day Cladocera, such as the cosmopolitan *Daphnia pulex*, live in small temporary ponds. In general, young individuals hatch in the early spring from sexual eggs produced by females (Fig. 1 C) and fertilized by males (Fig. 1 B) during the previous open season. These young are all females.

Parthenogenesis

In a few days each female becomes an adult 1 to 2 mm in length (Fig. 1 A), and produces eggs which she lays into her brood chamber (a cavity within the dorsal region of the animal). These eggs do not require fertilization. They de-



A. B. C.

FIG. 1

A. Female *Daphnia* with parthenogenetic eggs in the brood chamber. The swimming antennae are not completely shown.

B. Male *Daphnia*.

C. Female *Daphnia* with sexual or "winter" eggs in the brood chamber. These eggs are destined to be cast off in the protective egg-case or ephippium.

velop promptly and are discharged from the mother's brood chamber in forty-eight hours (at 70° F.) as young *females*. These young females themselves produce young within seven to ten days.[1] Successive clutches of young from a given mother are released each alternate day. The numbers in a clutch may reach thirty or even seventy. Under exceedingly favorable conditions a single mother may readily produce three hundred to six hundred young, all of which are females and are produced parthenogenetically—without any male intervention whatever. However, these extremely favorable conditions are seldom completely realized in nature, although they may be in laboratory cultures. But with even moderately favorable conditions, the number of descendants from a single mother and her daughters, etc., soon reaches prodigious proportions. Of course there are certain natural checks which tend to restrict the increase of population. Small fish, predacious insect larvae and other animals, even the lowly fresh-water hydra, prey upon Cladocera and limit their numbers so that many of them do not live to produce such large numbers of young. Further, many of the ponds which they inhabit undergo excessive evaporation and become much reduced in size. If not abnormally restricted in numbers by enemies, by food supply or by other factors, the Cladocera population soon becomes excessive, especially if the pond has been subject to recession.

[1] These time periods refer to ordinary laboratory temperatures (68° to 70° F. or about 20° C.). At lower temperatures the generation cycle is much lengthened; at higher temperatures greatly shortened.

Sexual Reproduction

Excessive population (which we shall refer to as "crowding") results in an

accumulation of the animals' excretory products. This accumulation of excretory products both in nature and in laboratory cultures results in the production of *male* young from the very eggs which under more favorable conditions produce only females. Extreme scarcity of food, which is also frequently a result of crowding, causes the females (sometimes apparently every female of the population of many thousands) to produce a markedly different type of egg. This is the sexual or so-called winter egg which can not hatch unless it is fertilized. After a period, sometimes less than a week, during which the sexual eggs are produced and fertilized, the entire Cladocera population is often destroyed by the stress of conditions—depletion of the pond, scarcity of food, the accumulation of excretory products, etc. If the pond does not reach complete drought or is replenished, a few may survive this period of stress and replenish the stock by the usual parthenogenetic (non-sexual) reproduction.

The fertilized eggs must have a resting period before they will hatch. This period may be prolonged for many months during which they may become dry or frozen without injury. They may hatch in the autumn with the replenishment of the pond by rains or they may remain dormant and not hatch until the following spring. This life cycle is diagrammatically shown in Fig. 2 B.

The utility of the sexual or winter egg in the life cycle of these animals is obvious. It tides the race over a period which neither the active animals nor their parthenogenetic eggs can survive. It hatches when favorable conditions again arise. Sexual eggs occur only two in a clutch in most Cladocera and only a small percentage hatches, under natural conditions probably, in most cases, less than 1 per cent. The adaptive advantage of the production of the sexual eggs at a time of crowded population and hence in great numbers is obvious.

The Advantages of Parthenogenesis

The utility of parthenogenetic reproduction in the life cycle is only a little less obvious. Whereas sexual eggs occur only two to a clutch and very few hatch, parthenogenetic eggs in many species may occur in clutches of twenty or many more. Nearly every parthenogenetic egg produces a viable young. Further, during active parthenogenesis, the population may be and usually is exclusively female. Here *every* individual is productive of young. If males did occur during this period they would be quite superfluous.

Parthenogenesis, then, is a method which accomplishes rapid multiplication and, with every individual of the race a productive *female,* the rate of population increase under favorable conditions is extraordinarily rapid indeed. This rapidity of parthenogenetic reproduction is an important advantage for two reasons. (1) Many Cladocera habitats are small temporary ponds which become dried up or otherwise unsuitable for Cladocera inhabitants early in the summer. A rapid multiplication of the population (derived from the few sexual eggs which hatch in the early spring) is essential if this favorable environment is to be utilized. Further, Cladocera, like all other living organisms, are subjected to relentless competition. Their failure promptly to utilize favorable environmental conditions would mean correspondingly increased success to competing species, reduced opportunities for themselves as a lagging species and reduced numbers of females (all of which may bear sexual eggs) and males to insure carrying the species over the ensuing unfavorable period. Cladocera species do vary in the rapidity of their parthenogenetic reproduction, but their world-wide distribution and their occurrence from the arctics to the tropics in nearly every pond apparently suitable for their habitation attest to their success in meeting competition and in sur-

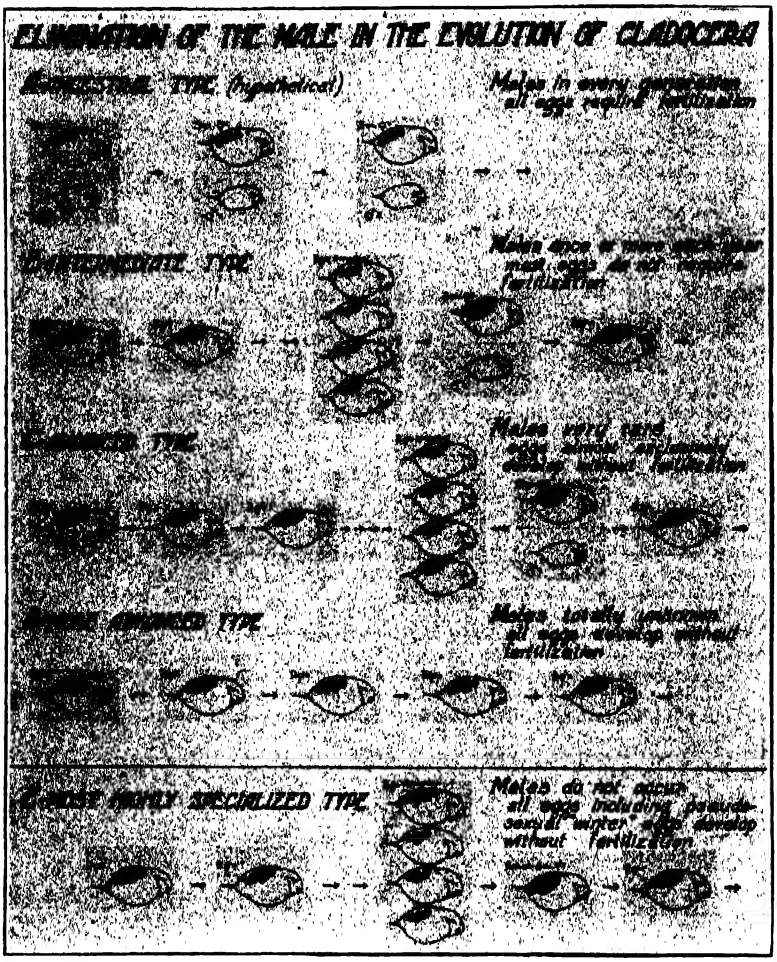


FIG. 2

A. The hypothetical ancestral type. Presumably marine and reproducing exclusively by sexual reproduction, males occurring in every generation.

B. The intermediate type. Lives in fresh-water ponds and temporary puddles. Parthenogenesis is the prevailing method of reproduction but males and sexual reproduction occur at one or more periods each year.

C. The advanced type. Lives in lakes and more nearly permanent ponds. Parthenogenesis is almost the exclusive method of reproduction. Males and sexual reproduction occur only under exceptional conditions of stress.

D. The more advanced type. Lives in lakes in mild climates and perhaps in permanent marshes. Parthenogenesis is the exclusive method of reproduction. Males do not occur.

E. Most highly specialized type. Lives in temporary ponds like ''B'' above. Parthenogenesis is the exclusive method of reproduction. Males do not occur. This type is unique in that it has retained the ''winter'' egg, which, however, is here a pseudosexual egg and not only does not require fertilization but can not be fertilized. It is apparently the type best adapted for continued existence in transient ponds.

viving unfavorable periods. (2) Rapid multiplication during the favorable period of the life cycle is a further advantage since it provides large numbers of females and males for producing the fertilized sexual eggs when the less favorable period comes and the sexual or winter egg alone can provide the means for continuing the race until another favorable period arises. The production of vast numbers of sexual eggs is essential to the perpetuation of the race. The sexual eggs are eaten by other animals; quantities are smothered by débris; vast quantities become stranded on the dry margin or the bottom of the pond, if it becomes completely dried up, and may be carried away by wind or other agencies or destroyed by other means; finally, under the most favorable conditions the hatchability of these sexual eggs is very poor. Except for the prodigious population of these animals, which parthenogenesis brings about in the comparatively brief favorable period, it is difficult to conceive that sufficient numbers of sexual eggs could be produced to insure carrying the species over from season to season. Here, as in many phases of nature, the opportunity ordinarily arises but once. Failure to utilize the opportunity for the production of the fertilized sexual eggs when it comes would mean destruction of the species in the pond in question. But such failure probably seldom occurs. These animals are so attuned to their ever-changing environment that the approach of unfavorable conditions in itself operates to bring about males and sexual reproduction. Thus it appears that the rapidity of parthenogenetic reproduction, especially promoted by an all-female population, is of great advantage in enabling Cladocera to utilize an environment while it is physically available—before the pond becomes dried up; and while it is biologically available—not largely preempted or depleted by competing species, and further to provide for the timely production of sufficient numbers of the fertilized sexual eggs to insure the perpetuation of the race.

The life history just cited as typical for the common *Daphnia pulex* with certain minor variations may apply to the vast majority of present-day Cladocera species. The decreased occurrence and lessened importance of the male sex during the greater part of the yearly cycle of these animals, as compared with most other living organisms, is apparent. It is equally apparent that there is a correspondingly increased rôle played by the female sex in the life cycle, during the greater part of which cycle the female carries on reproduction quite without male cooperation.

Three general groups of Cladocera species, which have progressed further in the elimination of the male sex than in the illustration above, show important modifications of the life cycle. These modifications of the life cycle can be more briefly stated than the general life cycle discussed above.

The Advanced Type

The first of these more highly specialized groups contains species like *Simocephalus exspinosus* which in nature less often have males and sexual reproduction than does *Daphnia pulex* of the intermediate group just discussed (Fig. 2 C). A statement for *S. exspinosus* may typify this "advanced" type. This species lives in general in cleaner ponds and more generally permanent ponds than many of the species belonging to the group previously discussed. It has a fairly rapid reproductive rate but, for some little-understood reason, less often attains a condition of extreme crowding. Possibly there is some natural check which prevents the development of acute overpopulation which so frequently occurs in the former group. It might readily be that they are less omnivorous in their food habits and that their numbers are held in restraint by food lim-

itations before extreme overpopulation occurs. There is, indeed, some positive evidence in support of this supposition. However this may be, the facts remain that *S. exspinosus* on Long Island lives in general in ponds (1) which contain less organic matter and are much less filled with bacteria and other lower organisms; (2) in ponds which are permanent or more nearly permanent, and (3) that in our experience this species in nature has very rarely been found producing males, while we have never seen the sexual eggs in nature. Yet individuals of this species may be found the year round. During the entire open season this species normally produces only parthenogenetic eggs following which a few parthenogenetic or reproductively inactive females live over winter under the ice and begin active parthenogenetic reproduction again in the early spring. Hence this species in suitable ponds may apparently continue indefinitely by parthenogenesis and entirely without males in the population. It is, however, capable of male and sexual-egg production and may readily be caused to produce both under appropriate laboratory conditions (crowding of the mothers for male production and scarcity of food for sexual-egg production). It may, however, also produce both these perquisites for sexual reproduction in nature, else its recurrence in some ponds which have become dry during the preceding season is not readily accounted for. In our experience males have been found in only one pond, which at the time of occurrence of males of *S. exspinosus* was heavily crowded with two different races of *Daphnia pulex* and contained moderately large numbers of two other species (including the *S. exspinosus* under discussion). The *Daphnia* races were producing vast numbers of males and sexual eggs at the time the less abundant species were found to be producing a few males. Probably sexual eggs of *S. exspinosus* also occurred but escaped observation, inasmuch as the pond became dry and the species nevertheless reappeared the following spring.

The situation in brief is this. *S. exspinosus* lives under circumstances which ordinarily permit it completely to dispense with males and sexual reproduction. Under exceptionally adverse circumstances, however, it may and does resort to sexual reproduction and thus the race is carried over by means of fertilized eggs to the next period favorable for its active life. Fig. 2 C is an attempt to diagram this life cycle.

The More Advanced Type

Another group of Cladocera, the "more advanced type," consists of certain lacustrine (lake-inhabiting) and probably some marsh-inhabiting forms, like *Bunops*, which live in more temperate climates. These forms occur the year round and are not known to produce males. They presumably have only non-sexual reproduction (Fig. 2 D). The writer has had little experience with these forms. It would be exceedingly interesting to test them in laboratory cultures to see if they have lost the capacity for male and sexual-egg production.

The Most Highly Specialized Type

The height of adaptation in the elimination of the male is seen in a unique form of the highly polymorphic *Daphnia* group found on Long Island. This constitutes the "most highly specialized" type (Fig. 2 E). This development is accompanied by a special adaptation to environmental conditions such as occur in small temporary ponds, like those inhabited by the type of the ubiquitous *Daphnia pulex* of the first group discussed. In this, the final group of Cladocera to be discussed, not only have the male sex and sexual reproduction been eliminated but, *mirabile dictu*, the winter egg has been retained. But, whereas in other Cladocera forms the winter egg is a true sexual egg and must be fertilized in order to develop, in this

form the winter egg develops without fertilization, *i.e.*, it is a *pseudosexual* egg. So complete is the structural and developmental resemblance of this pseudosexual winter egg to the winter egg (the true sexual egg) of other known Cladocera forms that we at first questioned its apparent development without fertilization. However, laboratory experiments demonstrated that this winter egg does develop, after the usual "resting" period, in spite of the fact that no males had been present in cultures in which it was produced. Considerable search among the population in nature and extensive laboratory experiments had already failed to reveal a single male of this cladoceran type. We must conclude that this form does not produce males. Males of other closely related *Daphnia* forms did not succeed in fertilizing this egg so that we conclude further that it can not be fertilized. Of still further interest is the fact (demonstrated by Dr. Franz Schrader, of Bryn Mawr College) that this pseudosexual winter egg in its development cytologically quite resembles the development of the ordinary parthenogenetic Cladocera egg. Hence it is apparent that in this form the winter egg, with its attendant advantages for the carrying over of the race from one favorable period to another, has been retained and yet the male sex has been entirely eliminated.

Cladocera happen to be better known to the writer than other groups of organisms. It is known, however, that among plants the common and very successful dandelion (among others) has dispensed with sexual reproduction. Similar examples from the animal side are rotifers and plant-lice, which may have only female population and uninterrupted parthenogenesis for long periods; and, as a more extreme case, certain gall-producing wasps which have only parthenogenetic reproduction and the male (which is here a rarity indeed) is quite functionless, both the sexes having lost their sexual instincts.

SUMMARY

The writer has attempted to show that with the lowly water-flea, as with certain plants and other animals, the male sex and sexual reproduction have in general come to assume a much smaller than the usual rôle and a smaller rôle than must have been the case in their ancestral forms; that in certain forms, the "intermediate" type, males and sexual reproduction have been eliminated for the greater part of the life cycle (though they, with the resulting winter eggs, do occur in periods of stress); that in another, the "advanced," group inhabiting permanent ponds, males and sexual reproduction occur with rarity, the animals under favorable conditions being able to live from year to year without resort to the sexual or winter eggs, although the species still possess the capacity for male and sexual-egg production and do produce these perquisites for sexual reproduction on occasion; that in another, the "more advanced," group inhabiting lakes which do not become dry or frozen, all individuals are apparently female, males and sexual eggs being unknown; and that finally we have a "most highly specialized" type, inhabiting temporary ponds, which not only is without the male sex but asexually produces the functioning winter egg which serves to carry the race through drought and winter.

This restriction and even elimination of the male sex seems attended by certain advantages. These animals by the rapid method of parthenogenesis (1) are able to take advantage more quickly of a favorable, perhaps transitory, environment and (2) are better able to meet the competition of other species. Furthermore, since females alone can produce eggs, the all-female population is a decided advantage (3) for quickly utilizing favorable conditions, (4) for providing vast numbers of females and males for the production of the fertilized sexual eggs, when the occasion arises, and (5) in the most highly specialized form for producing adequate numbers of the pseudosexual winter eggs.

REPETITION IN THE BREAKING OF HABITS

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NEARLY two years ago I put before the American Association for the Advancement of Science the outline of a method for dealing with undesirable habits, based on a theory with regard to the rôle of repetition in habit formation: a theory which is almost the reverse of that which William James impressed upon American psychology so thoroughly that it has been practically accepted as axiomatic. Since publishing this outline,[1] I have received friendly suggestions from various psychologists as to the priority of other authors in formulating the theory, but I am still unable to see that any of these other authors would have been understood to have suggested the hypothesis which I am presently holding unless the reader were previously familiar with the hypothesis. The controversies over the function of frequency have been, so far as I am able to understand them, limited to the questions whether frequency, *per se,* is the sole factor in habit formation or but a primary factor among others or merely a minor factor. No one seems to have doubted that repetition *per se* is a factor. Of course, the specific question as to the number of repetitions does not enter here, for no one has ever denied that a single performance may in certain cases fix a habit. The point has been that it is the *doing* of an act which contributes to making the act habitual; and that if a single doing is not sufficient, several or many repetitions may be. Just what constitutes the *doing* of an act has not always been carefully scrutinized, but very frequently, doing or acting has been considered naïvely in the simple physiological sense. The vogue of the "conditioned reflex" terminology, with the accompanying amazingly naïve selectiveness of interpretation, has intensified this unanalytic attitude on the part of contemporary psychologists, or some of them.

In brief, I have pointed out that the theoretically possible rôles of repetition, *per se,* in habit formation, are three, and I have for convenience designated them as the *alpha-hypothesis,* the *beta-hypothesis* and the *gamma-hypothesis,* respectively. Stated somewhat carefully, the alpha-hypothesis is as follows: "A response (that is, even a single response) to a given stimulus pattern definitely increases the probability that on the recurrence of the same, or substantially the same, stimulus pattern, the same, or approximately the same, response will occur." Stated concisely, the beta-postulate is that response, in itself, has no effect on the probability of the same stimulus pattern producing the same response, and the gamma-postulate is that response decreases the probability. Adopting the beta-postulate as an obviously fertile one, I have therefrom deduced the hypothesis that repetition may be employed in the dissolving or breaking of habits as well as in the formation of habits, and by a simple comparative method formulated a tentative method for such employment. I will not repeat the details, which may be found in my original article along with the results of the first attempts at application.

Various individuals have since made trial of the method I suggested, some in consultation with me, some without. Their results have been as varied as might be expected. Technique is all-important, and must be based on careful psychological analyses (not psychoanalyses) of the cases. My surmise that dif-

[1] *Science,* 67: 360–362, April 6, 1928.

ferent ages of patient and different types of habit require different techniques is apparently verified. Dr. Blanche Weill seems to be attaining success in the treatment of enuresis in children; others have been discouraged after a few trials. The technique with this particular habit seems still crude. Dr. John Bentley has achieved remarkable success with a group of confirmed finger-nail biters of college ages. A few weeks of practice for a few minutes a day suffice to let the nails grow out to normal length and the habit is broken; but the patients being then left to themselves, many relapse, as might be expected. The follow-up treatment for this type of case is manifestly of great importance. For many types of case, the scales of frequency, duration and character of follow-up practice need to be worked out.

Thumb-sucking, in four- and five-year-old children, yields interesting results in the few cases where the method has been applied. The children grasp the method and seem to understand its purpose. Strong obstacles develop; the child devises ingenious methods of diverting its attention from the important details during the practice period, etc. These are overcome by the patience and tactfulness of the experimenter, and the habit rapidly dwindles to a low stage, where it remains. The explanation apparently is that the child loses the incentives which have previously been supplied by the mother's scoldings; the habit becomes almost negligible and the child finds no bad results from it, and hence loses interest in overcoming it. Technique here is needed.

Sexual perversions in adolescents and adults seem to offer the easiest problems of all, perhaps because the individuals are anxiously interested in breaking them. In the few cases where I know it has been tried, masturbation and homosexual practices yield readily to treatment provided the treatment can be applied under the direct supervision of the psychologist (which of course is not possible in some cases), and relapses are not difficult to forestall.

Some applications have been made to stammering cases, and these seem to offer opportunities for useful work, but the development of the adequate technique is still a formidable task. From the results with one case, of typical sort in the young adult, which I have now on my hands, I believe the technique can be developed. Even brief treatment has produced a remarkable improvement, greater than I have ever obtained in any case with other methods. I am inclined to think now that the most economical and adequate treatment will occupy a few days at a time, these times being separated by several weeks. Since in no case do I expect a cure or decisive improvement inside of a year, whatever method be employed, the working out of the time schedule for the treatment is an important matter. It is probable that in many other types of case time is an important element, and the most adequate utilization of the time-stretch is hence a vital problem.

It is to be understood, of course, that the techniques we are using and the better techniques we are seeking can be adequate only against the habit as habit, and will suffice only in those cases in which the original causes have ceased to operate, as they have in very many cases of stammering, for instance. Where the primary causes are still operating, not only must the habit be broken up, but the causes must be ferreted out and eliminated. It appears, however, that the technique necessary to break up the habit offers excellent opportunities for correlated work in discovering the causes, where these are still operating.

The importance of technique is illustrated by the report of Dr. G. Wakeham[3] of his own attempt to apply the outlined method to the elimination of certain errors which he habitually made in the

[3] *Science*, 68: 136–137, August 10, 1928.

rendering of certain passages of the Bach-Taussig Toccato and Fugue in D minor. The selected passages were played ten times daily, with the wrong notes deliberately and attentively put in, the other conditions of the method being fulfilled. On the fifteenth day the whole piece was played without error. After several errorless performances Dr. Wakeham attempted to demonstrate his success to one of his pupils—and played the passages with his habitual errors.

Now, I am not claiming that I would have predicted just that result, for my knowledge has developed slowly in respect to this hypothesis and method. But it is now fairly clear that the technique employed by Dr. Wakeham was not the most adequate. What I would now prescribe would be to follow the successful performance achieved without audience by a practice performance with the errors, in the presence of the pupil, and then to attempt a perfect performance in his presence. If this should be followed by an error-practice performance in the presence of a small group, I venture to predict that a successful perfect performance could be expected before an audience. The conditions of erroneous performance in the past and the mental attitude towards the errors *in the presence of others* have been influential in this case. In the case of a novice or even an advanced student who has habitual errors to correct but who has not felt humiliated by them the conditions might be much simpler.

I can not refrain from mentioning here an amusing case, on which my data are not complete. A lady in a distant state described to me in a letter a certain morbidity with which she was afflicted. Apparently she dipped into medical books and journals, for she wrote that when she read about any of the bodily organs, she had unpleasant feelings in (or referred to) her own organs: and if she read a description of symptomatic feelings she experienced those symptoms. She indicated that she knew it to be morbid imagination, but nevertheless it was inconvenient.

I explained to her, of course, that on such sketchy data and no possibility of supervision I could not make any definite prediction or promise of results, but I suggested a technique which was well worth trying. I suggested that each day she select a set of symptoms, and then for a few minutes revel in them. I gave her detailed instructions as to mental attitude (or thought processes, if you prefer that term), and warned her that persistence for some weeks might be required. A few months later she wrote, in effect, that she had had a terrible time with the method, but had stuck to it, and was now entirely free from her morbid troubles. This, of course, sounds like a patent medicine testimonial, but I have not had time to follow up the case more definitely.

Some cases of successful application of this method have been reported by others, and many cases will be in shape to report on before long. There is, however, a field of application which opened up accidentally which I wish to mention because of its theoretical implications as well as its practical possibilities and also because I have results to report obtained only on myself, and I would like to invite others who may be interested to make trials. Like many other people, I forget names of persons and places, and have had a number of vexatious habits of forgetting specific names. I can always find amusing psychoanalytic explanations for the forgettings, but that doesn't help matters any. By accident, I thought of an application of the method under discussion, and since then have been having a good time demolishing my specific amnesias as fast as they present themselves. Perhaps a description of the first case may make the conditions clear.

On the boulevard between Baltimore and Washington there is a small settlement where the boulevard makes almost

a right-angle turn. I had occasion during the winter of 1927–28 to drive the boulevard one or more times a week, and noted that in approaching this spot I never could recall its name, nor could I recall it at other times. On various trips, after passing the place, I tried to memorize it by different methods, including the method of repetition, but without success. Last fall, as I approached the turn, it occurred to me to try the negative method. Upon reading the name, therefore, I tried to forget it—an attempt of a sort which most of you know is most baffling. This, however, did not last more than a minute (or a little over a half mile), as I could check later. I have never had the least difficulty in remembering *Beltsville* since. The sagacious critic will point out that in the effort to forget the name I was giving exceedingly good attention to it, but the fact remains that by this brief effort I accomplished what prolonged and repeated effort of the positive type had failed to bring about.

Since that time I have applied the method to other names with one significant failure. This summer in Algeria I passed the striking boiling springs near the railroad from Constantine to Alger which are named in English translation the "baths of the damned." Shortly afterwards I found that I had forgotten the Arabic name and had to look it up in a guide-book. A little later I had again forgotten it, so after looking it up again I made effort to forget it but this did no good, and I finally dropped the matter. However, in writing this paragraph, I find that *Hammam Meskoutime* comes to memory immediately. This failure under quite different conditions from those of my other trials suggests that there may be a line of useful experimental work to be discovered here.

This application, aside from possible practical values, suggests an explanation for these curious and vexatious forgettings, namely, that positive effort to remember a name which for one or another reason does not recall immediately may make future recall still more difficult, even impossible. At any rate, whenever I disremember something, I now happily dismiss the vacancy as quickly as possible. Here again, James came close to suggesting the method, but not the theory. If my observations should be confirmed, it will be evident that the Freudian doctrine of repression needs more than a little revision.

Enough of these instances, which of course are not experimentally valid and prove nothing. This year I am returning to my laboratory after two years of wandering in the wilderness. I plan to attack the problems of the alpha, beta and gamma postulates from as many directions and as fast as possible. As I said at the beginning of this paper, I think we have here a theory which is either quite absurd or else has far-reaching implications. We might as well face the possibility that we shall eventually be forced to the conclusion that no habit formation is possible without ideational activity, or thinking; a conclusion to which the so-called "conditioned reflex" experiments, in my limited understanding of them, already point. But of course, if we should admit that the white rat thinks, that does not imply that his ideational processes are of the advanced type of humans (or of *some* humans).

The bearing on the theory of dreams I have indicated in my primary article, and I have had no opportunity to make any observations on that point.

In regard to the therapeutic applications, I must point out that I have at present neither expectations nor hopes of the development of methods which can be applied by the layman or by the psychiatrist untrained in psychology. The method, as it looms up, involves delicate psychological points of ideation and motivation which demand expert

acquaintance with the psychology of the learning process and with many other details of mental life. The psychological principles, I apprehend, must be applied to each case after careful study. I do not find that it is easy for the psychologist (in which class I place myself) to grasp the conditions involved, and many seem to have assumed that the basal principle involved is simply that yielding to a habit tends to break it, which is really more nearly the opposite of the actual principle.

In criticizing the method in its crude state, many theoretical objections have been raised by various psychologists, and the possibilities of interpretations on the basis of various other hypotheses, including the psychoanalytic ones, have been pointed out. I do not think that at the present stage of the game these are important, although they may be later. For the present, I am willing to waive interpretations and go after experimental results. We have here certainly something new, however closely it may have been missed in the past; something which is intensely interesting, to me at least, and something which opens new experimental possibilities. To a prosaic psychologist like myself, this leaves nothing to be desired but work.

COLOR IN SCIENCE AND POETRY

By Dr. GEORGE R. STEWART, Jr.

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WHEN the perfect history of English literature is written—a volume which will bear as its imprint *Jerusalem, the Golden*—I feel sure that it will contain some such sentence as this: "One of the important events in the history of poetry during the nineteenth century was W. H. Perkin's discovery in 1856 of phenyl-phenosafranine ($C_{27}H_{25}N_4Cl$)."

To understand why this respectable chemist, Mr. Perkin, may some day be ranked with Keats and Browning we must skip nimbly back a few centuries—let us say, to the time of that so-called Father of English Poetry, Master Geoffrey Chaucer. None of us can read Chaucer's poetry much without becoming strangely conscious of the, to us, naïve and childlike repetition of a few primitive colors. Hardly ever do we find any distinction of hue or shade. The "floures white and rede" bloom, and bloom again in almost every mead. Now and then they become "blew and white and rede" and once, to our astonishment, actually "white, blewe, yellowe, and rede." In this same stanza is also mention of green and silver, but with this one great burst of dissipation—it occurred in his youth—Chaucer reached his limits as both nature observer and colorist, and thereafter maintained an impeccable respectability. To the modern mind Chaucer appears to have developed his color sense about as far as the child who with his crayons creates a blue-blue sea, a yellow-yellow beach and a green-green tree without idea of more subtle conceptions.

For contrast let us look at some of Miss Amy Lowell's work. This procedure will be greatly to Chaucer's disadvantage. To begin with, we notice that the modern poet has lost nothing which the older poet had; red can still be as red and white as white as in the flowers by the Canterbury road:

High-footed cups for green wine,
And incense-burners yellow as old Llama books
With cranes upon them.
Blue porcelain for the Altar of Heaven,
Yellow for the Altar of Earth,
Red for the Altar of the Sun,
White for the Altar of the Year-star.
—*A Legend of Porcelain.*

But, over and above this, modern poetry can show a new technique of hue, tint and shade; red is not always red. In a few of Miss Lowell's poems, with no attempt to be exhaustive, I have listed seventeen varieties of redness. There are "crimson butterflies," "peach-bloom silk," "dawn-red wine-cups," "vermilion fishes," "cocks with rose-pink legs," "ochre-red sails," a "scarlet dress," "pink water reflected from the carmine-tinted mountain summits," "rose-red light," "blood-orchid tips of mountains," "copper," "maroon," "ruby," "salmon," "carnation," "magenta." These are not merely words used for the sake of variety, but they actually suggest different, often strikingly different, mental images, all of which Chaucer was wont to group meanly under the one word *red*.

Since no one can successfully maintain that Chaucer really was an unsophisticated child of a simple-mannered century, the explanation of his crude technique must be sought elsewhere. Once considered, the question is not difficult. His poverty-stricken color vocabulary does not prove that he had no sense of hue, or even that he did not care to play with nuances as well as any imagist. But he could do no other. Like many another medieval man of

genius he was cabined close by lack of tools. He was an Abelard studying philosophy without Aristotle, a Roger Bacon scanning the heavens without a telescope. In short, Middle English simply did not contain the necessary color terms. Those words which give the glow of multicolored light to the pages of a modern poet were in the fourteenth century either not yet invented or not yet metaphorically employed.

Chaucer's whole possible color vocabulary did not equal the number of words which Miss Lowell had at her command for a small fractional part of the spectrum. The standard colors of his language—the whites, blacks and grays neglected—were brown, red, yellow, green and blue. Dun and fallow were in use, but these, as Dr. Johnson maintained, were barnyard rather than poetic hues. Blo, which Chaucer used once, preserved a doubtful distinction from blue. Purple was a common enough word, but he used it only in translation or with classical reminiscence; except for its occasional heraldic use I should doubt whether Chaucer actually knew what hue it denoted. In addition to these were a few terms which were just beginning metaphorically to be used for colors instead of for dyestuffs and materials; the Wife's scarlet hose must have suggested a fabric as well as a hue to the earliest readers of the Prologue. In fact, any one considering the matter historically must admit that Chaucer was actually as much of a pioneering colorist as Amy Lowell. She coined such compounds as "rose-green" which left our modern conservatives gasping; probably the conservatives of five hundred years ago gasped too when they found Chaucer, under stress of finding six rhymes, once using azure abstractly to mean blue instead of concretely to mean, as every one knew it did, lapis lazuli. Langland and Gower did not do such things, but were content with good old red and green. Chaucer, again, seems to have been the first to use as color words ruddy (except as applied to the complexion), sunnish, citron and rosy. To arrive at a simple term for so common a hue as orange was, however, clear beyond him, so that twice we find the interesting and accurate but ludicrously clumsy circumlocution—"betwixt yelwe and reed."

This constitutes, I hope, a sufficient defense of Chaucer himself, but at the price of a severe indictment of the English of his time. Once more, however, we must not assume that this childlike color vocabulary indicates that medieval England had attained only a childlike state of culture. The world has never seen more highly developed cultures than those of Periclean Athens and Augustan Rome, and yet Sophocles and Vergil were little, if at all, better equipped than Chaucer to express shades of color. These languages of the classical world had adapted themselves for the subtlest play of dialectic or the most complicated legal relations, but they could not distinguish between blue and violet. Plato (to judge from his extant writings) could with difficulty have mastered words for ten distinct hues; for such a common shade as pink Aristotle was forced to coin an awkward "white-red" (λευκέρυθρος). Vergil was little better off; although succeeding to the Greek heritage and able to piece out his scanty Latin vocabulary with borrowings, he could distinguish only a round dozen of colors. He was richest in reds, but besides the general term (*ruber*) was able to denote only a few shades, to be roughly equated with modern English ruddy (*rubicundus, rubens*), orange-red (*rutilus*), rosy (*roseus*), blood-red (*sanguineus, cruentus*) and crimson (*puniceus, purpureus*). Horace, Ovid and Catullus can succor Vergil's vocabulary with only a few unimportant terms.

Two passages from the literature of the highly developed period succeeding

the Augustan display an even comic weakness. When Pliny the Elder, cultured man of the world and eager observer, attempted to describe the varieties of hematite, he stammered like a child. "There are three kinds," he wrote, "red, and less reddish, and half-way between these." Junior in the fourth grade would hardly be allowed such language to-day. Aulus Gellius a few decades later, playing Boswell to a Johnson by Favorinus, lets us see that the Romans of that period themselves were acutely conscious of this weakness. Gellius wrote:

> Favorinus, the philosopher, going to visit Marcus Fronto . . . wished me to accompany him. At his house, in the presence of many learned men, much was said concerning colors and their names, that there was great variety of colors, but that the names for them were inadequate and uncertain. There are more discriminations in the perceptions of the eyes than in names and terms for colors, for to say nothing of their other peculiarities the simple colors of red and green have each but a single name, though many different varieties.

Favorinus, who was the spokesman of this opinion, was, in the symposium which followed, refuted by Fronto, who was able to show that the Latin language by the aid of Greek borrowings could actually distinguish five shades of red. Any modern man in culture comparable to Favorinus or Fronto should be able to mention twenty at least. One is left amazed that in Rome itself "in the presence of many learned men" the question of verbally distinguishing more than one shade of red was subject for argument. For contrast, I may note that recently a group of twenty university students at my request wrote down as many words for shades of red as they could in five minutes. The lowest score was seven, the highest fourteen, and the total, duplication eliminated, thirty-five.

We have wandered a long way from Mr. Perkin, but we are ready now to take the back trail simply by asking the old question, "Why?" How comes it that in our day colors may glow a dozen to the page while in former ages that number would have exhausted the poet's whole hoard? A complete exposition of cause and effect is, of course, impossible; I wish, however, to point out the workings of one important agency, nothing more or less than that old enemy of poetry, science. Our age in nothing differs more from both the medieval and the classical than in our organized and always successfully advancing science. In one way or another it is to this scientific research, beginning in the seventeenth century, that we owe much of the color richness of English poetry. I shall illustrate with three examples, one from each of the past three centuries.

In the month of February, 1671/2, one of the greatest of all scientific experimenters, Sir Isaac Newton, recorded the result of passing a pencil of light into a darkened room and by means of a prism analyzing it into the spectrum. Sir Isaac, if we can accept the famous cat and kitten story, had somewhere in his unsurpassed brain a streak of childishness, and for no other reason apparently than the great tradition of seven, he invented for the spectrum the seven so-called primary colors. Even for these, however, terms were not readily available. "Red, yellow, green, blue," he noted first; then came, as the wording seems to indicate, a striving for a term, and the great brain so apt at voyaging through strange seas of thought alone was hard put to it to produce "and a violet-purple." Followed, one imagines, a rumpling of the divine forehead until there came forth—"together with orange and indico." One notices that instead of naming the colors in logical, scientific order from one end of the spectrum to the other he wrote down those first for which he had definite terms. Purple was a common word of the time, but did not fit exactly, so that

he qualified it with the not yet established term violet.[1] In later writings he became bolder in his use of language, and dropped the purple. Orange and indigo Newton did not quite coin, although before his time they almost always carried the suggestion of the fruit or the dyestuff. But if he did not give the name, he at least supplied the local habitation; violet, orange and indigo thenceforth had their definite places in the spectrum. They became standard colors—a precise image every time one looked at a rainbow. Men since Noah, poets by the hundred, had seen rainbows, but had generally accepted them as the grace of God. Only when the man of science made an artificial rainbow and considered why, other than by divine caprice, orange lay beside red instead of beside blue—only then were definite terms found necessary. In the vigorous scientific controversy which followed certain of Newton's declarations, the names of his seven colors were popularized, or at least became known to men of culture. In the next century with Thompson and Gray they began to work into poetry. Without this aid of science one wonders how Edwin Arlington Robinson could have described his Isolt of the violet eyes, which, so often mentioned, give to her at once the touch of romance and of individuality.

In the eighteenth century one of the most active fields of science was that external and descriptive side of botany and zoology called natural history. In Sweden Linnaeus, in France Brisson and the great Buffon, in Germany Borowski, in Russia Pallas, in England Latham, Pennant, Goldsmith and White—these are only a few of the many who either as investigators or as popularizers furthered the work. Accurate observation in the field of natural history demands a keen sense of color; accurate record of this observation demands an adequate color vocabulary. These writers upon natural history had the color sense, and by sheer force of necessity they made their color vocabulary. They were not always masters of language; their compounding of words was sometimes infelicitous; but, by and large, they accomplished much.

To appreciate the difficulties of the case for an English writer, consider yourself setting out to describe and distinguish 133 varieties of parrot—that gaudiest of birds—with a Chaucerian or Vergilian list of colors. This was approximately the predicament of Latham, for example, when preparing his "General Synopsis of Birds." To write at all he had to be able to distinguish colors, and he did distinguish them. To him violet, which the poets still treated gingerly, was a commonplace. For a while he adopted a half-way attitude on orange by calling it orange-color, but before he got far with the parrots he dropped the idea of the simile to the fruit and wrote simply orange. For Chaucer a parrot would probably have been merely a bird, "yellow, blue and red," or else he would have taken refuge in similes and heraldic terms, as he did in describing Chantecler. But Latham buckled valiantly to the task and his vocabulary flourished. He enlisted the suffix *-ish;* he made use of the homely garden compound of pea-green; he borrowed from the Latin luteous, rufous and fulvous; he ransacked all nature for lilac, brimstone, vermilion, chestnut, ash, cinereous, peach-blossom—any stick to beat a dog, and any word to describe a parrot.

To show Latham's minute observation and—of more interest to us—his color vocabulary, almost any of his descriptions can serve. His thirteenth species, the Blue-headed Parrot, is as good as any.

[1] Violet, in fairly common use in the fifteenth century, later fell into disuse.

The upper mandible is yellow, with a pale ash-coloured tip; the lower of a plain ash-colour; eyes in a naked yellowish skin: above, the plumage is green; beneath yellow green: the forehead inclining to red: the head itself is blue: throat violet, inclining to ash: sides of the neck luteous: hind part of the neck, back, and scapulars, green: the lower part of the back, rump, and upper tail coverts, of a shining green: fore part of the neck, yellow green, lightening into yellow at the sides: from the breast to the tail greenish yellow: wing coverts green: quills green above, the inner webs and tips deep ash: beneath cinereous; shafts black, except that of the first feather, which is whitish: the two middle tail feathers are greenish, verging to blue at the ends: the next the same, but yellow within: and the four outer ones on each side green on the outer webs, luteous on the inner; the webs above black, beneath white; all but the two middle ones tipped with yellow, and the whole tail yellowish ash-colour beneath: the two middle feathers exceed the outer ones by near four inches: legs blueish: claws grey.

In this one passage Latham is able to distinguish twenty shades with some accuracy and to find words for them without undue awkwardness.

Gilbert White, contemporary and friend of Latham, is also of interest because his "Natural History of Selbourne" is one of the few links in English between science and *belles lettres*. With White we see at work the same urge which motivated Latham. He peers over dead specimens or spies upon living ones, seeking to distinguish hue and shade for identification. If his vocabulary was not as varied as his contemporary's, this was probably because he was under the necessity of describing only the respectable fauna of English moor and dale instead of the bedizened denizens of tropical forests. The method was the same, as he poured over a lifeless bird and wrote, "Its *cere* and feet were yellow, and the circle of its eyelids bright yellow. . . . As it had been killed some days, I could make no good observation on the colour of the pupils and *irides*." (Letter 11.) Again, he catalogued on the plumage of a certain lark, a dull-colored bird at best, six shades; here it was dusky brown, there simply dusky, elsewhere tawny, in other parts white, milk-white and yellowish white (Letter 24).

Compared with the naturalists, the leading poets of the same decade show a really lamentable poverty of color. Goldsmith displays less variety than Chaucer; Cowper used neither violet nor orange, and in his many volumes of poetry distinguished hardly a sufficient number of shades to serve for one bird.

But a new generation was at hand. Latham and White both published in the eighties, a decade in which flourished a group of eager boys, ardent lovers of nature, who in a few years transformed English poetry. In the eighties little Walter reveled in the beauties of Teviotdale, young William absorbed nature by the English Lakes, elsewhere were Samuel, Robert, another Walter and two Thomases. In the course of a few years infants were born and named George, Percy and John. Approximately a generation after the great burst of writing on natural history these children grew to manhood and brought their poetry to fruition. The relation of the former to the latter is thus certainly *post hoc*, and also in the color vocabulary at least, I believe, *propter hoc*.

The Romantic poets displayed the most developed use of color in English verse to their time. The Elizabethans were indeed often lavish in the color words, but their terms were in many cases connotative or suggestive rather than distinguishing. Hell-black, heaven-hued, and so forth, have fine poetic possibilities, but would be of little value for the classification of birds. Shakespeare and Spenser did not separate rose and pink, did not use violet or any word but purple for that whole group of shades and could with difficulty (Spenser, I think, not at all) distinguish orange. They were stronger in reds. The Ro-

mantics, on the other hand, equally well supplied with reds, were much better off for the colors farther along the spectrum. Purple, for instance, they supplemented with violet, amethyst, hyacinthine and lilac, not to mention any number of qualifying adjectives, such as deep or faint, coupled to all these.

Two phases of the situation are of special interest. One is that many new color words (olive, pea-green, brimstone, lilac, ultramarine, for instance) previously popularized by the naturalists turn up in Romantic poetry. The other is the use of a developed system of qualifying colors, of which the language had not previously made much use. Even the Elizabethans seldom coupled an adjective with a color or combined two colors. These became, however, favorite devices of the writers of natural history. To return to Latham, we find constant use of combinations like deep-blue, bright-yellow and dull-red, together with simple and complex color coupling such as orange-red, greenish-yellow, yellowish-orange-brown. Combinations of these sorts are characteristic also of Romantic poetry. In Wordsworth alone occur among others deep yellow, dull red, pale blue, together with red-brown, olive-green and black-blue. The immense possibilities of these two systems of modification were first recognized by science under the stress of necessity, and then adopted by poetry.

In the seventeenth century poetry had drawn aid from physics, the most ideal of sciences; in the eighteenth from biology, the most picturesque of sciences, but in the nineteenth its debt was to be owed to the most utilitarian, grimy and odoriferous of all sciences—chemistry. In 1856 a precocious young investigator oxidized commercial aniline with potassium dichromate, and began a brilliant career which eventually gained him knighthood and an article in the Encyclopaedia Britannica. The new compound was a dyestuff producing a brilliant and unusual purple. Possessing acumen for commerce as well as for science, Mr. Perkin patented the process of manufacture, and also borrowed from the French a trade name, *mauve*. Both as a dye and as a word mauve was an immediate success. Two years after its commercial production was begun the word was well on the road to establishing itself; before the end of the century it was naturalized enough to permit the formation of *mauvish*; it is now a standard word in prose and verse; its latest achievement is to attain symbolic value, and to be used in Mr. Thomas Beer's "Mauve Decade" to characterize the last years of the century which witnessed its invention.

But the direct debt owed by poetry to Sir William Henry Perkin is only a small fraction of the indirect one. For, lured by his success, hundreds of eager organic chemists, like prospectors to California a few years earlier, rushed into that vast unexplored region where lay hidden the precious aniline dyes. In 1859 the second dye was perfected—a piercing purplish red. Already the year had seen one study in red blotched at the command of Napoleon III among the vineyards by the Ticino. After this victory of Magenta the second dye was named. Thus by the twists of linguistic fortune a French flower and an Italian town became English colors.

Ever since this beginning the dyeing industry has exercised influence on our vocabulary. Since the development of the aniline derivatives the dyer has had at command a wealth of color such as never before. He and his ally, the fashion-maker, having selected a shade can continue to produce this exact shade as long as demand lasts, and can therefore with advantage and propriety give it a definite name. The result is that now the most complex color vocabulary is neither with the poet nor with the naturalist, but with the dressmaker. A

page from *Vogue* would give Latham names for colors, knife-edged distinctions, which he could not match from all his 133 parrots. Some advertisements from *Harper's Bazar* make Amy Lowell seem as primitive as Chaucer. I mention only a few shades which are now merely technical terms in fashion, but which may some day be material for poetry: Queen blue, navy, orchid, palmetto, athenia, nude, cyclamen pink, flesh, peach, Chinese yellow, monkey-skin, cocoa, Goya red, Alamanda green, Sistine blue, praline. A single page of the catalogue of a mail-order house—surely nothing could be more commonplace—yields among dozens of others Nile green, popcorn, gull, Napoleon, Oporto, cerise, henna. Some of these are glossed, but the glosses themselves presume a highly developed color vocabulary. Nile and Palmetto green are apparently considered standard colors, and not explained at all, although I have not found the latter in any dictionary. Autumn glory is translated as bright henna, and hydrangea as new powder blue, on the assumption, apparently, that these latter shades would be known to every one. Another mail-order catalogue devotes an entire page to a color glossary, listing and describing a total of 336 shades.

Fashion shades and their names are, in short, legion. A single manufacturer advertises seventy, another seventy-two, for one season. Many of these names are, true, ephemeral, to be forgotten by next year; nevertheless, they are definite names for definite shades, and where they fill a want are likely to survive. Let it be recalled that several of our now accepted color words began primarily in fashions—mauve, magenta, lavender and (it would hardly be too much to say) scarlet. Of more modern examples Alice and Navy blue, and Nile green have survived the vicissitudes of years, and may almost be said to have established themselves. Beige came into use some five years ago, and is now such a standard color of reference as to boast rose beige, French-beige and other subvarieties. I have seen the parvenu listed on equal terms with white, blue and green, aristocrats of ten thousand years' standing.

For illustration of how fashion-words have affected the vocabulary of at least the one half of the American nation, let me record a conversation which I recently heard; neither party follows a profession concerned with color:

"Yes, my bridesmaids were in a faint pink, very faint, well hardly a pink at all—a flesh."

"Half of mine were in orchid, and the others in a darker shade, a deep orchid, I guess you would say. Not a purple of course, more like a lavender.

"Lilac?"

"Yes, something like that."

Of all the colors mentioned, Shakespeare and Milton would have recognized only purple. The talkers, to be sure, seem to flounder a little for words, but one must remember that they are attempting to induce a precise image out of the four million possible ones of hue and shade. And to give them their due, they succeed remarkably well. Two hundred years ago, no one, neither philosopher nor poet, would have been able even to try.

While science in the past three centuries has been supplying words, it has also been increasing our vocabulary in more subtle ways. It has undoubtedly rendered us more sensitive to color. Chaucer and his fellows *may* have been keenly alive to hue and shade, but our general experience in such matters would teach us that, more likely, they were not. Without words to emphasize and without need to classify they probably let all reds pass as red and were content. Science, classification, has changed this. To Gilbert White straining his eyes over the dead lark, to the chemist watching the marvelous play of color in his Fehling's test, to the physi-

cian searching through his microscope for the tints which distinguish the eosinophile from the polymorphonuclear, to the housewife matching scientifically dyed thread to scientifically dyed fabric, to the rancher's daughter isolated beyond the last filling station nervously ordering a spring dress from Sears Roebuck or Montgomery Ward, to the very tot in school studying a color chart arranged according to the discoveries of physics, the accurate distinction of color is the business of every-day life.

The very standardization produced by science, so often bewailed as having given the *coup de grâce* to poetry, has also by a curious back-twist really aided poetry. As long as a certain shade of yellowish pink existed only in the flesh of an apricot, in a momentary shade of the morning sky and in an occasional gown, language could never afford to have a special word for it. But when by modern methods of color production the same exact shade may glow from a million scarfs in one month, a word becomes to some necessary and to all convenient, and apricot is thereupon a color as well as a fruit. Thus the poet gains a fresh aid to blazon forth anew that oldest of poetic subjects, the rosy-fingered Aurora, and so display his contempt for science, destroyer of beautiful myths.

Truly, great is science, and her name is above all kings. We still stammer, we are little better off than was Chaucer for descriptions of smell; science has as yet done little to explain and codify. There is as yet no smell spectrum. If there ever is, we may predict that words will be called into being, and with words poetry. Christopher Morley will no longer be forced to:

> wonder why the poets tell
> So little of the sense of smell.

Just as Napoleon, greatest enemy of perfidious Albion, could not march his battalions against Wellington without the help of English shoes, so poetry is glad to gain new vigor by the aid and succor of its age-old mortal adversary.

THE SCIENTIFIC STUDY OF HUMAN BIOGRAPHY

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THE students of the historical, humanistic, social and physical sciences are united in a common interest in human biography. They want to understand the factors which favor high productivity in philosophic speculation, scientific investigation, literary creation, economic enterprise and political management. They would like to know how, within the same field of activity, "temperamental" and "environmental" influences combine to produce different constellations of traits and interests. The ever-present problem is to account for the appearance of and the differences manifest in Shakespeare and Goethe, Descartes and Kant, Newton and Einstein, Bismarck and Napoleon. Or, more generally, the task is to isolate the operative factors in the determination of typical views of the world and typical levels of creative activity.[1]

Many streams of investigation have convincingly shown that a human life, viewed at any given cross-section, is the outcome of formative factors of many kinds. The cultural *milieu* leaves its mark on the speech, morals, manners, tastes, ambitions and loyalties of the individual. The phantasy life of the person gives him a private world which distinguishes him from his fellows in the same cultural environment. No individual can be completely defined as the phenomenon observable at the intersection of culture planes; it is a commonplace that members of the same family, exposed to the same religious, racial, partisan, national, educational and occupational influences, display wide differences in traits and interests. The physiological and anatomical make-up shows several typical deviations within the range of the "normal."[2] Differences in glandular function may make puberty crises, menstrual cycles and climacteric changes more serious for one than another. Physiological and anatomical facts, such as shortness or tallness, fatness or thinness, may expose the person to respect or contempt in specific cultures.[3] The neurological and intellectual coordinations of individuals differ very markedly from one another. There are important differences in such fundamental processes as those of perception, some individuals retaining eidetic imagery throughout their adult lives. Pathological elements in the ordinary organic processes are not to be underestimated. Some types of disorder bring ascertainable consequences for the efficiency, mood and preoccupation of the victims. The pathological changes associated with senility are especially significant in politics, where old men occupy high diplomatic, administrative, legislative and judicial posts. The psychopathological disturbances are particularly prominent in many active and productive lives. Medical psychology has recently come to stress the importance of repressions in the production of neurotic symptoms, neurotic character traits, psychotic symptoms and perversions.[4]

[1] One may refer in passing to the work of Dilthey, Spranger, Klages, Jaspers and their circles in this connection.

[2] A readable, succinct summary is that of E. Miller, "Types of Mind and Body," New York, 1927.

[3] H. Hoffman has outlined a method of approach to the study of heredity factors in his "Das Problem des Charakteraufbaus," Berlin, 1926.

[4] An evaluation of existing personality documents is in my article, "The Problem of Adequate Personality Records: A Proposal," *American Journal of Psychiatry*, May, 1929.

That the writing of human biography is in an unsatisfactory plight is manifest in the omissions and mistakes which are to be found in the current output. In the universities, human biographies continue to be written under the sole jurisdiction of separate departments, often ignoring the interpretative concepts which are successfully used by men in other departments of the same institution, or applying them in amateurish fashion as mere figures of speech. This is especially the fate of such psychopathological terms as "complex," "repression," "sublimation," "compensation."

The obvious escape from the difficulties of the present situation is by way of a procedure which familiarizes the apprentice biographer with the chief technical tools of the major fields which converge upon the interpretation of human reactions, and to give him the benefit of sustained technical criticism in applying them to a definite case.

It is scarcely feasible for the student to shop around among the departments of internal medicine, neurology, psychiatry and psychopathology, psychology, anatomy and physiology, besides the departments of social science, history and the humanities of the university. If the student attends clinical demonstrations in internal medicine he may learn something about the symptoms of many diseases, but all that is directly valuable to him is the recognition of those disease conditions which have been demonstrated to have special effects upon the mental state of the sufferer. Such correlations emerge as medical psychology develops. It should be possible to render the current data readily accessible through lectures, demonstrations and bibliographies. Moving-picture films may be developed to show how the diagnosis is made, and the psychological effects of the disease upon the patient.

The prominence which has been given to pathological and physical scientific conceptions in this brief statement does not mean that the chief aim of biography is to become pathography. Of pathographies there are many, since Möbius introduced some discipline into the field.[5] Biography is a larger field, requiring the analysis and resynthesis of the significant features in the individual's total history.

The central nucleus of those interested in the problem of more adequate human biographies might very well constitute themselves into an institute of human biography, composed of a historian, sociologist, political scientist, economist, jurist, humanist, historian of science, historian of philosophy, psychiatrist and psychopathologist, doctor of internal medicine, geneticist and psychometrician. Temporary consultants could be attached to the central nucleus as specific studies warranted.

Since the modern university makes so many demands upon the time of its members, any task which is not institutionalized is prone to be neglected. It is therefore desirable that the chief centers of learning both here and abroad develop mechanisms of the type proposed. Each individual institute might guide the research of both pre- and post-doctoral workers.

If the retrospective interpretation of men's lives is to be kept abreast of specialized scientific progress, the development of such a converging attack seems to be imperative.

[5] See the recent summary of this entire literature by Wilhelm Lange-Eichbaum, "Genie-Irrsin und Ruhm," München, 1928.

THE SPARROW-HAWK'S FIRST FLIGHT

By RALPH E. DANFORTH

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To see it throw itself into the air before it had had any chance to practice flying gave a thrill worth long and patient efforts. Reared in a hole high up in a great tree the young sparrow-hawks could not even stretch their long wings adequately to give them what we would consider a conception of what flight would be like. The five young hawks had taken turns looking out of the round hole to see a small portion of the world into which they were soon to thrust themselves upon untried wings. They had seen their parents fly with consummate skill and speed. They themselves had remained crowded together in a hollow; jostling one another for the large insects brought to them; crying tremulously with insatiable appetite; clambering over and falling back upon one another; exercising indeed but not flying. Could a moment come for each one when it would risk a twenty-eight-foot fall to earth, throw itself with closed wings out of a round hole and fly to a neighboring tree? That was what I wanted to see with my own eyes.

The American sparrow-hawk, ***Falco sparverius sparverius*** L., is not as closely related to the sparrow-hawk of England as it is to the hobby, merlin and kestrel, which are true falcons. Our American sparrow-hawk is a small falcon. Early in April a pair selected a hole in a large elm near our home and forced out the starlings which had used it ever since the flickers had made it and reared a single season's offspring in it. Our local flickers have to carve laboriously a new hole every season because long before they return the next spring the starlings have been living in it. The pair of sparrow-hawks, however, had no regard for the starlings' desires and took possession and kept possession even during two distressing snow-storms that came before the month of April had ended. I well remember their sitting near the nest-hole, feathers fluffed out, through two long, tedious northeast snow-storms, storms during which many robins and bluebirds perished for lack of food.

I kept an interested eye on their activities through April, May, June and the first half of July, but will not take your time to describe these. Early on July 18 one came out; his parents were feeding him in the top of a neighboring elm. I resolved to try to see the next one leave the hole, but in this I was to be disappointed, for although I watched many hours that day, and began my vigil at daybreak the next morning, Number 2 slipped out in a moment when I was otherwise engaged. Morning, afternoon and evening I watched, for there were others to follow, and some of them seemed about on the point of leaving. They would lean far out of the hole until it seemed as though they would fall. The hole opened somewhat downward, as it was on the under side of a huge limb, a little above the point where the main trunk forked to form the crown. The birds took turns at their circular window, sometimes gazing out from far within, sometimes with their guinea-pig faces framed by the opening, sometimes with half or more of the body projecting. Their curious bills were so small and down-curved that they appeared not to have any beak, while the bizarre markings on face and head made them resemble strange mammals rather than birds. When the bird looked down-

ward revealing the back of the head with its two black spots surrounded by buff-colored rings it seemed to have owl's eyes in the back of its head. Sometimes they were silent, with head bobbing up and down in a half timid, half menacing way. Again they were noisy, tremulously calling their parents for food. From my screened porch below or from my second-story window I could watch them clearly.

The parents were always wild and suspicious if one came out near the tree. On the morning of July 20, 1929, I again arose at the song of the robin and trained my field-glasses out the open window, propping them so that the hole in the elm would be in the center of vision whenever I might choose to lower my eyes to look through them. Most of the time I preferred to watch with unaided eyes. No sign of activity among the sparrow-hawks was yet to be seen. The parent birds were doubtless roosting not far from the two young which had left the nest. Long before the sun gilded the sky, however, the parents were actively feeding the young, both those outside and those within the hole. Soon they stopped feeding those in the hole, except at long intervals, feeding the liberated birds more often. The most active bird left in the hole had a very light breast with scarcely any streaks upon it. I thought surely this would be the next to leave. In fact, I had thought it would leave the day before. It was the one to lean farthest out and to spend more time than its share in so doing. But a less assertive bird with dark stripes on its breast replaced it at the window for a few minutes, then suddenly and silently flew to an elm eighty-one feet away, catching itself with difficulty in some small twigs at the base of the leafy crown of the tree. Instantly a parent bird appeared from some tree-top and followed it closely to make sure that it alighted successfully. Reassured that all was well with the young one the parent departed as silently as it had come.

After a few minutes' rest the young one began climbing up to larger branches. It seemed to gain strength rapidly. Resting and climbing by turns it soon gained the top. In climbing it both walked and hopped, using the wings freely.

In half an hour the light-breasted one launched out and flew strongly and unattended to an elm 138 feet distant, alighting in the great fork at the top of the trunk, a point higher up than the hole the bird started from. It too shortly began climbing the tree. Soon Number 5 left the hole, but not until it had tried to start but changed its mind after it had put its left wing fully out of the hole. It was the only time I had seen one of those birds with a wing out of the hole before they left the hole for good. It with difficulty pulled that long wing back into the hole after it. Then it came out again, doubtless uneasy at being left all alone for the first time in its life, and it too flew 138 feet, catching the leafy frond surrounding the bole, some ten feet below the top of the trunk.

None of the young returned to the hole. They may never enter one again until they set up housekeeping for themselves. Toward noon the mother bird did enter the forsaken hole just for a moment, possibly from idle curiosity.

It is unsafe to ascribe human motives to a bird or other animal. We often err in reading the motives of other human beings. But if all creatures have common instincts and ancient hereditary backgrounds, we may sometimes be right when we guess what goes on in the mind of a lower creature.

What does the first flight mean to the little falcon that has never been out of the hole? From many observations of these young sparrow-hawks I gained the impression that they are very sordid and

selfish. When their instinct to master the air becomes strong enough to overpower their instinctive fear of falling, the thrill they get is probably more physical than intellectual. They have, indeed, been training their truly wonderful eyes on earth and sky, on objects near and far, for a long time before they fly, and can see much better than any human beings, and there must be added satisfaction when they can see from a tree-top much more than from the nest-hole. But fancy that *you*, and not the sordid bird, were brought up in a hole in a tree, along with various brothers and sisters of about the same age, the size and form of the bird, but possessing your human intelligence and poetic fancy; what would the first flight mean to you?

The change from life in the hole to life in the open world and sky comes with the suddenness of death. From the time of your earliest memories until the instant you darted forth upon the free air your whole life was crowded, with those of your brothers and sisters, in a small hollow in a tree, and poorly lighted from a still smaller opening to the outside world. After long waiting and growing and scrambling for food brought by those all-providing parents that came and went on silent, speedy wings, you began to clamber up to peer out of that hole of mystery through which food and parents alike had always come. What dreams and thoughts you would have about that bountiful outside world, stretching on and on apparently without end or limit. As your strength increased you would lean out of the opening, and, with your head and eyes well out from the tree, you could fancy yourself almost free; yet always your view would be so limited to that one center, and so cut off by the tree itself and by the many other fixed objects. You could not feel the things you saw, or reach them. What you saw would mean but little to you, but all the while your eyes would be training and your wing muscles growing. The problem of exercising the wings in cramped quarters would be difficult. The wings would be too long to move as in flight. If you are a human being who worries you would worry about the proper preparation for that first flight. When the time came for you to lean far out and spring into the air the impulse would need to be very strong, and you would say it took a lot of faith. It would, indeed, be like the faith to die and believe that it would be the portal of a supremely larger life. You never would have tried it. You had caught only broken glimpses of it from afar. The actual proof that the wings would work would come only when it was too late to draw back into the dark hole. It would be fly or—what? You knew not what, in case you did not fly.

Then the soft, elastic air buoyed you up. With a swiftness you had never known before you sped through space. You could not keep this up long. You must alight somewhere. The inviting green of the elm fronds offer safety and rest. Yes, you feel them with your feet. You are safe. You have conquered thin air. The sky and all beneath it is yours. No longer will a small hole restrict you. No longer will its rough-hewn walls confine you and blot out your vision. You will not enter that narrow life again, not even to sleep. You will climb, in a few moments, to higher twigs. Then climb again, and yet again, until you are comfortably perched in the very top of that great and massive tree. The warm sun beats upon your whole being. Overhead nothing but the sky limits you and your vision. No half-decayed wood to roof you over. No quarrelsome companions to crowd you against cabin walls. If they bother you now there is all the universe around you. New sights in infinite variety surround you

on all sides and above and below. You have graduated from a narrow life to one of wide immensity.

We might compare the experience to the change of caterpillar to butterfly, but it would not be analogous, for the long wait in the pupal stage is so different from the fraction of a second that it takes to spring into the air when already leaning far out into it. It might be likened to the germinating of a seed and its marvelous change into a plant, with all its larger life. But that process is again very slow—a gradual transformation. I can not think to what to liken that sudden, instantaneous change from life to larger life, from a cramped and very confined life to life of unlimited possibilities, unless I compare it with death.

The little falcon must fear the leap. He takes it.

THE WINTER WREN, HIDDEN ARTIST OF SONG

By RALPH E. DANFORTH

CHESTERFIELD, MASS.

THE winter wren is a true bird-lover's bird. Many people will not know him really well. He is not rare but eludes them. He is small and dark and continually crawling under rocks, logs, sticks and whatever vegetation may be around him. Yet he is uniquely beautiful in form, manner and marking. His song is his supreme charm. Whoever hears this song and learns to know it has enriched his life. For all time my store of joy is greater because the winter wren's song has added to it. A trip to the summer haunts of the winter wren will prove a good investment if the lover of sweetest sounds and melody succeeds in hearing the song of the winter wren.

Thoreau heard and described the song when on a trip in the White Mountains, yet he probably never knew what bird had sung that song. He was unable to follow up the sound, having lamed himself. Yet description and habitat fit the bird so well that those who know the winter wren agree that such was the unknown bird which so charmed this great man of the wilderness.

Burroughs calls the winter wren a "marvelous songster, in speaking of whom it is difficult to avoid superlatives," and adds:

> He possesses the fluency and copiousness for which the wrens are noted, and besides these qualities, and what is rarely found conjoined with them, a wild, sweet, rhythmical cadence that holds you entranced. I shall not soon forget that perfect June day, when, loitering in a low, ancient hemlock wood, in whose cathedral aisles the coolness and freshness seem perennial, the silence was suddenly broken by a strain so rapid and gushing, and touched with such a wild, sylvan plaintiveness, that I listened in amazement. And so shy and coy was the little minstrel, that I came twice to the woods before I was sure to whom I was listening.

Florence Merriam Bailey writing of first hearing the song of the winter wren called it "the event of the summer in the woods. Full of trills, runs and grace notes, it was a tinkling, rippling roundelay."

These few quotations show that one is in good company when praising the winter wren. Yet few indeed are those who know him well. Each spring and summer the winter wren invites you, reader, to join the company. Pleasanter invitation never sounded through the woodlands.

This dark little cinnamon-brown bird first made himself known to me when I was a small boy in southeastern Pennsylvania. His dapper appearance, the black bars across his sides and belly, his

mouse-like habit of creeping under brush-piles, rocks and overhanging banks of brooks captivated my boyish fancy. But I did not hear him sing until years later in the high hills of New England. I have only heard the winter wren sing in the spring and early and middle summer. In the higher parts of the Alleghanies he does nest as far south as North Carolina, but at ordinary altitudes he is not often found nesting and singing south of Massachusetts. Further south he livens the winters with his distinctive chirp and sprightly activity.

Interest in this little bird makes one want to know more about his family. There are hundreds of species of wrens in the world, some in the Old World but most of them in the tropics of the New World. This is unusual, for most bird families represented in both the Old World and the New have more species in the Old World. It would be fascinating to follow these many wren species in tropical America. We have but few species in the United States, fewer still in Europe.

One who knew only the house-wren and the short-billed marsh-wren would be surprised to know that some wrens really can sing the sweetest of music. Bewick's wren is an excellent singer, and a Carolina wren wakened me with the regularity of a clock one winter in the mountains of North Carolina. It was a joy to be wakened by sounds so clear and strong and peaceful. I have ever since loved the song of the Carolina wren. It is one of my favorite bird-songs. Our ancestors in England probably knew but one species of wren, but it was a sweet singer and often sang in winter. They called some other small birds, as kinglets, "wrens" also.

In Porto Rico I found no wrens. Several of our northern warblers go there in winter, but the odd little tody, with its short tail and long bill, is the most wren-like in habits of all the native Porto Rican birds. Its back is as green as a leaf and its throat is red.

To know the winter wren through and through find him in his northern breeding range or in his mountain fastnesses. Hear that soul-stirring melody and follow it, if you can, to its feathered source. This past summer several have been singing in Chesterfield, Massachusetts. In the woods beyond the "Gorge" one sang through the spring and early summer, and wandered frequently as far as the "Bend" where many swimmers enjoyed its songs as an added touch of wildness in the wooded surroundings. They often asked what was that "canary-like" song so much sweeter and wilder than any canary song. None knew it until told. As far as I could learn none followed it to its author. I was glad they did not disturb it. We heard them also this summer on Mount Monadnock in southern New Hampshire. I saw one there as late as the end of September, scrambling over and under huge rocks in a rocky ravine.

The winter wren combines two strongly contrasting types of individuality. It is exceedingly self-contained, retiring, secretive, yet it pours forth a wealth of song for the world to enjoy which stirs the souls of all hearers. It gives with a prodigal heart of its stored-up wealth gleaned from heaven's sunshine, woodland fragrance, crystal rocks and crystal springs. It gets inspiration from hundreds of wild associates, odd or beautiful. It breathes ever the purest air, it sees always the most beautiful trees. It associates continually with the flowers of God's creation. Stars at night pour down their benediction upon this sprite of the wild. Storms contribute their primal vigor to its wild song. Sunlight caresses the winter wren with gladdest touch. These enter into its song. Clear sweetness and energy and joy are its music. From the fulness of a royal heart its throat pours forth melody.

If the winter wren is a recluse in the wild, it is continually gleaning treasure to offer the world in its song. Only the best of what it receives comes out for others to enjoy. Industriously it collects from a hundred sources, beauty, nourishment, light, color, interest, fragrance, and when these have been thrice refined this generous little being fills the woodland air with them.

But, one may ask, how many can hear the song thus sung in the wilderness? Should the bird not be brought into metropolitan concert halls? The most picturesque portions of the wilderness are the only fit setting for that song. Shall we bring the planet Venus into man-made halls, or view it in the sky? So the place to hear the winter wren is in the limitless open. In nature as God made it one may hear this song as God's creature makes it. Leave your cities and your buildings and your cars behind when you seek the winter wren. Leave your cares and your finances, your foibles and regrets. Leave your jealousies and aches. Just go. Go in search of a rare soul, bigger, perhaps, than yours, though it be tied to a body so tiny. Go where the hermit thrush sings and hemlocks are fragrant. Where flowers and ferns and mosses grow in wildest abandon. The air is purest where the winter wren sings. Light is most sparkling there. It is the place where peace abides. Hear him, see him, know him and carry back something fine and abiding which was not in your heart before.

THE PROGRESS OF SCIENCE

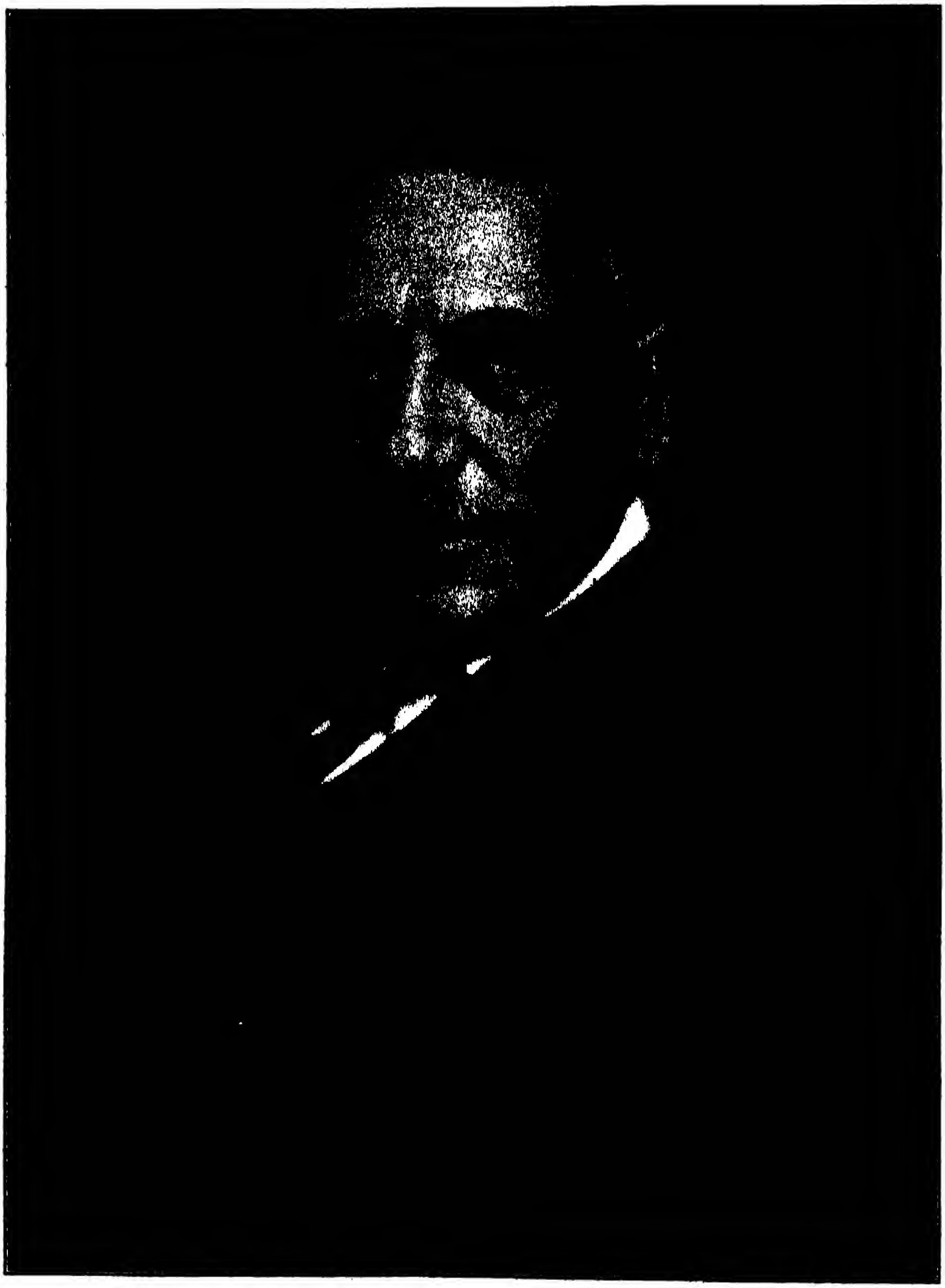
THE ANNUAL MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

The annual meeting of the American Association for the Advancement of Science and associated organizations will be held at Des Moines, Iowa, from Friday, December 27, 1929, to Thursday, January 2, 1930. This will be the eighty-sixth meeting of the association and the first to be held in Des Moines. It will probably not be as large as some recent annual meetings but the main fields of science will be well represented and this annual week of American science will be a very full one. All who are interested in the advancement of science and education are cordially invited to attend any of the sessions devoted to the reading of papers. A large number of lectures and addresses of general interest will be given and the exhibition of scientific apparatus, materials and books will be very attractive.

The Des Moines meeting will be held under the presidency of Dr. Robert A. Millikan, director of the Norman Bridge Laboratory of Physics of the California Institute of Technology. Dr. Millikan will give a public talk in the Shrine Temple on Sunday afternoon, his subject being "The Alleged Sins of Science." The retiring president of the association this year is Professor Henry Fairfield Osborn, eminent paleontologist and educator, president of the American Museum of Natural History, New York City, who will be the main speaker at the association's opening session in the Shrine Temple on Friday evening. Professor Osborn's address will be on "The Discovery of Tertiary Man." The annual Sigma Xi lecture will be given on Saturday evening, by Dr. George H. Parker, professor of zoology at Harvard University, who will speak on the general aims of men and women of science. Addresses will be given by the retiring vice-presidents for the several sections of the association. The Josiah Willard Gibbs lecture, of the American Mathematical Society, will be given on Monday afternoon by Dr. Irving Fisher, of Yale University. The Committee of One Hundred on Scientific Research is arranging a symposium on the economic status of research workers.

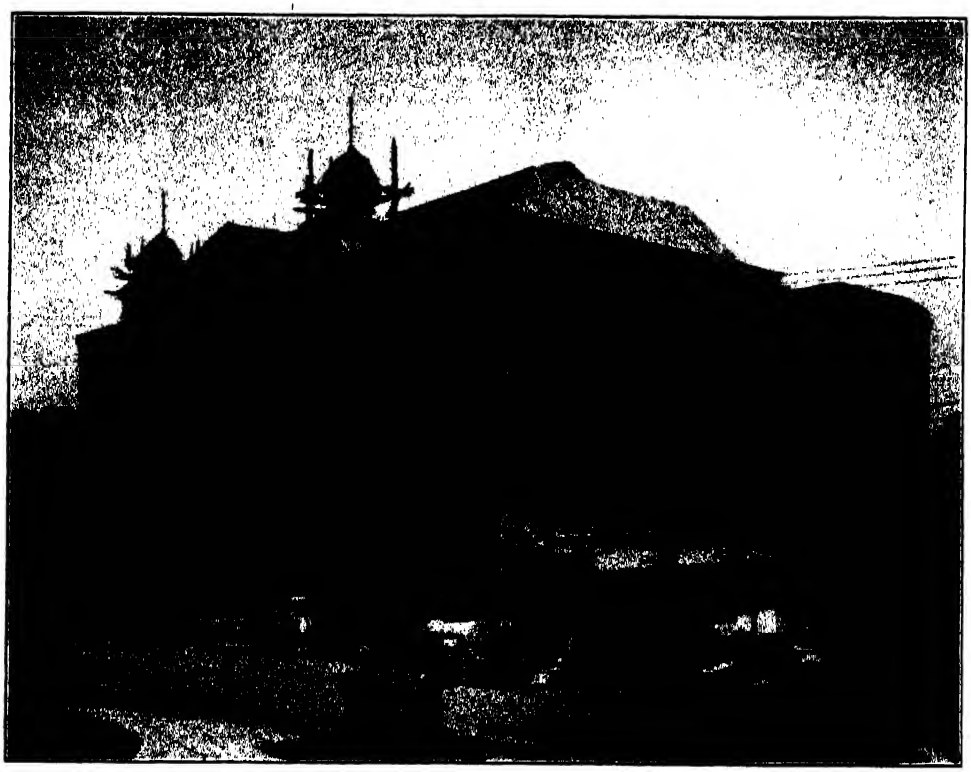
The preliminary announcement of the Des Moines meeting makes up most of the issue of *Science* for November 29, which presents many details about the meeting, including instructions regarding reduced railway rates for those who attend. It contains information about the program of each of the sections of the association, including the societies that are to meet with it this year. Those who do not receive the official journal, *Science*, may secure free copies of the preliminary announcement by addressing the permanent secretary's office, Smithsonian Institution Building, Washington, D. C., as long as the supply lasts. The general reports of the meeting are to be published in two special issues of *Science* for January 24 and 31, and free copies of these may be secured in the same manner.

The Press Service of the American Association is making arrangements by which scientific news from the meeting will be readily available to newspapers and news agencies, and a number of radio talks by leading scientists are to be broadcast from Des Moines in the meeting period.



DR. HENRY FAIRFIELD OSBORN

RETIRING PRESIDENT OF THE AMERICAN ASSOCIATION, WHO WILL GIVE THE PRINCIPAL ADDRESS AT THE DES MOINES MEETING. DR. OSBORN IS PRESIDENT OF THE AMERICAN MUSEUM OF NATURAL HISTORY AND RESEARCH PROFESSOR OF ZOOLOGY AT COLUMBIA UNIVERSITY.



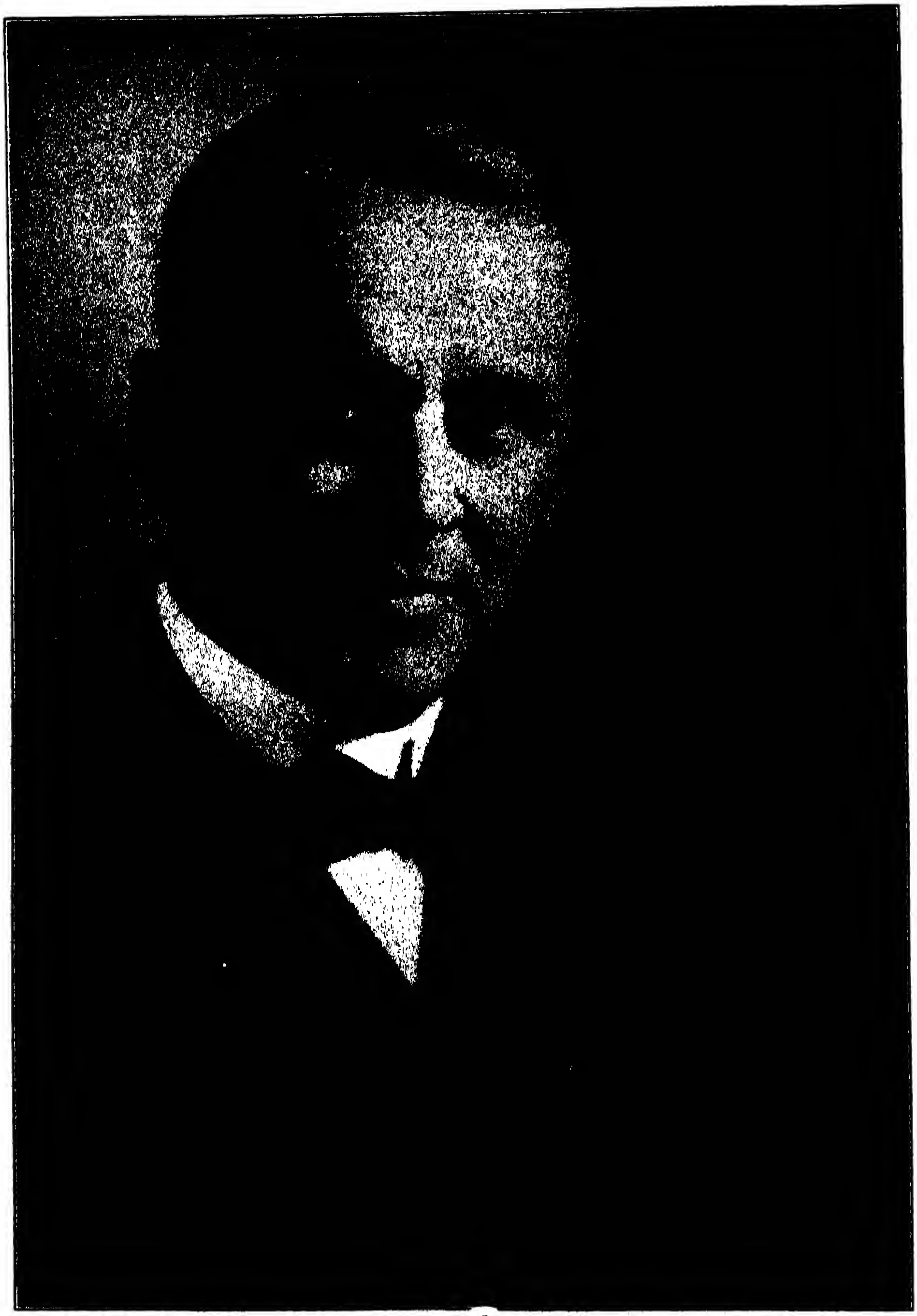
THE SHRINE TEMPLE AT DES MOINES

WHICH WILL SERVE AS THE HEADQUARTERS OF THE ASSOCIATION. THE AUDITORIUM HAS A SEATING CAPACITY OF FOUR THOUSAND PEOPLE.

DES MOINES AS A PLACE OF MEETING

DR. D. W. MOREHOUSE, president of Drake University and chairman of the local committee, writes that the first Des Moines meeting of the American Association for the Advancement of Science is an occasion of great moment to the State of Iowa. He says that every scientific worker or teacher has reserved the dates December 27 to January 2 for the past three years, looking forward to this meeting with great enthusiasm and anticipation. The Iowa Academy of Science has fostered the project with untiring energy and timely assistance. The citizens of Des Moines are said to count it the most significant gathering they have ever had the honor to entertain. The Chamber of Commerce, through the secretary of the Convention Bureau, has actually made the meeting possible, first through its financial support, but even more significantly by its enthusiasm and personal work during the last three months.

Des Moines is a city of diversified interests. It is not primarily agricultural, industrial or commercial, but it is a center of education and culture. Some years ago an eastern visitor expressed his surprise that he found Des Moines not a western agricultural town, but a center of culture and education. A European traveler, B. Ifor Evans, in his book, "Encounters," writes: "The unexpected gives the element of fun to life; it shows the greatness of the pat-



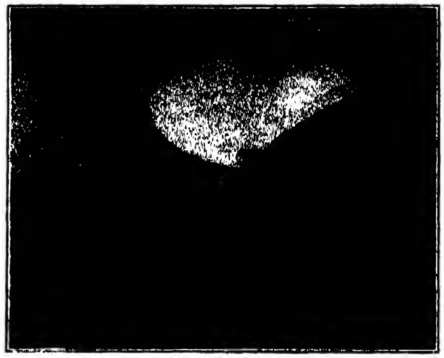
DR. ROBERT A. MILLIKAN

PRESIDENT OF THE AMERICAN ASSOCIATION. DR. MILLIKAN IS DIRECTOR OF THE NORMAN BRIDGE LABORATORY OF PHYSICS AT THE CALIFORNIA INSTITUTE OF TECHNOLOGY.

tern of the game. I remember one night in the Middle West coming to the town of Des Moines in the State of Iowa. And in my folly I had expected the men of Iowa to talk of corn, mighty and arrogant corn, taller than Babel. Instead a man came out to meet me at Des Moines and took me to an observatory and showed me the stars. 'That brown chocolate smudge,' he said, as I looked down the telescope, 'that is a star which is being born.' . . . It had taken years for the light of that chocolate smudge to reach the world. For a moment one seemed to rise out of the Middle West, to stand above earth, to be at rest in the mind of God. . . ."

Des Moines has entertained some of the largest national conventions, such as the National Education Association, the National Physical Education Association, the Imperial Council of the Mystic Shrine, the Grand Army of the Republic, the National Conference of Social Workers and the Lions International.

The Fort Des Moines Hotel is the general headquarters for the association. It is just three blocks from the Shrine Temple, which houses registration, exhibits and all general session lectures. The section headquarters are in the five leading down-town hotels. The sections A—Mathematics; B—Physics; C—Chemistry; D—Astronomy; H—Anthropology; I—Psychology; K—Social and Economic Sciences; L—Linguistics and Education, and M—Engineering, have selected for their headquarters the Fort Des Moines Hotel. Section F—Zoology, and affiliated organizations have chosen Hotel Savery. Section G—Botany, and Section F-G—groups related to both Zoology and Botany, will be quartered at the Chamberlain Hotel. Section E—Geology and Geography, has chosen the Brown Hotel. Section O—Agriculture, will have headquarters at the Randolph Hotel. Section N—Medical Sciences, will be located in the Commodore, a beautiful apartment hotel in the residential section of the city.



THE FOYER OF THE SHRINE TEMPLE

These headquarters, with the exception of Section N, are all within easy walking distance of each other and of the Shrine Temple. Most of the section programs are held in their respective headquarters, except in the case of joint sessions where larger accommodations are required, and even these will not be over five blocks from any one headquarters.

All the general session lectures will be held in the Shrine Temple, one of the most beautiful auditoriums in the west. The main hall will accommodate over

THE DRAKE UNIVERSITY MUNICIPAL OBSERVATORY

WHERE THE SESSIONS IN ASTRONOMY WILL BE HELD.

four thousand people. The exhibits of the association will occupy the basement, and the beautiful lounge, adjoining the auditorium and having easy access to the basement, will be used for the association reception.

The local committee has tenaciously held to the idea of centralizing the meeting so that all who attend will have the opportunity of seeing other workers in their fields and hearing a diversified program. There are a few exceptions, however, to this arrangement, notably part of the program of Section G—Botany, will be at Iowa State College, located thirty-seven miles north of Des Moines, and Section D—Astronomy, will hold an afternoon session at the Drake University Municipal Observatory, in the western part of Des Moines.

A new departure for the Des Moines meeting is a number of non-technical lectures for the general public and the school pupils. It is hoped that this will increase popular interest in science by allowing the leaders and men of scientific accomplishment an opportunity to disseminate the results of science to the general public and the younger generation who will carry on the work of the association. Extra-mural lectures have been arranged in some of the leading cities of the state, affording those who can not attend the meeting an opportunity to become familiar with the work of the association.

THE CENTENARY OF THE DEATH OF THOMAS YOUNG[1]

One hundred years ago there died in London one of the most versatile men of all time, Thomas Young, M.D., F.R.S., one of the eight foreign associates of the National Institute of France.

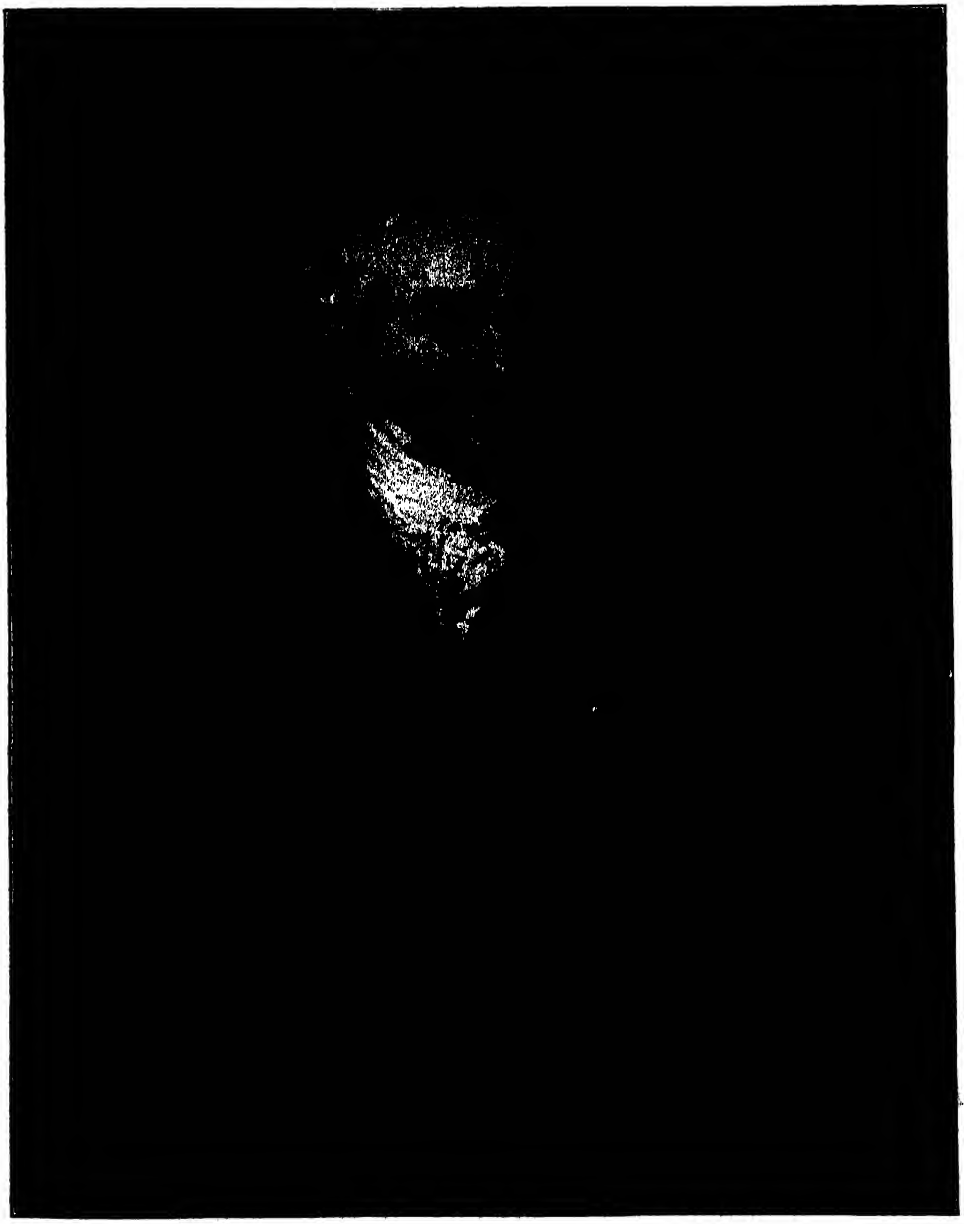
His parents were Quakers, and he maintained throughout life strict adherence to the moral principles of that sect, though he relinquished the external forms as unimportant and a hindrance to social contacts. His maternal great uncle, Dr. Richard Brocklesby, was a leading London physician. When his nephew was eighteen years old the doctor introduced him to the inner circles of social and literary metropolitan life. His social success was immediate, and he remained to the end of his life a brilliant member of London society. He studied medicine at London, Edinburgh, Göttingen and Cambridge, commencing practice rather late in life. His uncle at his death left him his town house with his library and paintings and a considerable fortune in money. He became physician to St. George's Hospital, a post which he held throughout his life.

During the first two years after commencing practice in London he was professor of natural philosophy at the Royal Institution. The lectures he delivered there were published in 1807 in two large folio volumes which were for years a standard work.

As a boy he was unusually bright, having learned to read by the age of two years. He had a remarkable memory and great aptitude for learning languages which he mastered with precision. At the age of fourteen, on being asked, probably in a patronizing manner, by one of his uncle's friends to write for him a copy exhibiting his excellence in penmanship, he administered a gentle rebuke by writing in excellent style a copy in *thirteen different languages!* Before he was twenty-one he had produced a work on the eye which resulted in his election to fellowship in the Royal Society.

He was fond of athletic sports, particularly of equitation, in which he ex-

[1] A more extended paper, read before the Thomas Young Memorial Meeting of the Optical Society of America at Ithaca, New York, October 24, 1929, will be published in the *Journal* of the Optical Society of America.



THOMAS YOUNG
1773–1829

celled, and was an accomplished musician and art critic. Although an excellent physician and writer of medical works, he is best known for his work in physiology and in physics. He made a series of remarkable measurements of the eye and founded the theory of color vision later extended by Helmholtz and held in high regard to the present time. He applied his talents to an investigation of the dynamics of the circulation with excellent result. The student of elementary physics soon learns of Young's Modulus of elasticity, but he is best known for having revived the undulatory theory of light and for devising crucial experiments on diffraction in support of this theory. The theory of these experiments he worked out with consummate skill.

He was frequently asked to serve on commissions appointed by the government to investigate and report upon scientific questions of public importance, and for many years he was superintendent of the *Nautical Almanac* and secretary of the Board of Longitude. He wrote learned treatises on the theory of tides and on correction of ships' comtary of the Board of Longitude. He was the inventor of the revolving drum chronograph still in universal use. At the request of one of the large life insurance companies he undertook extensive actuarial studies.

An achievement which illustrates particularly well his remarkable versatility, because so far removed from his better-known scientific activities, was the discovery of the key to the interpretation of the Egyptian sacred characters or hieroglyphics. Visitors to the British Museum may still see the famous Rosetta Stone on which is engraved a proclamation written in Greek, in Coptic and in hieroglyphics. It might seem an easy matter to translate a passage accompanied by two ready-made translations, but the hieroglyphics are a species of picture-writing, and it was not then known what language, if any, they represented. Young determined that they had in certain circumstances phonetic values and laid the foundation for their more complete understanding.

Of all his successors the one best qualified to pass upon his merit was Hermann von Helmholtz, himself famous as physician, physiologist, mathematician and physicist. In his popular lecture on vision Helmholtz says:

> He was one of the most keenly intellectual men that has ever lived, but he had the misfortune that his sagacity too far surpassed that of his contemporaries. They were amazed at him, but could not generally follow the keen flights of his combinations, and so the bulk of his most important thoughts remained buried and forgotten in the great folios of the Royal Society of London until a later generation, by gradual progress, rediscovered his discoveries and satisfied itself of the correctness and convincing power of his conclusions.

Athlete, musician, connoisseur of art, classical and oriental scholar, mathematician, actuary, physicist, physiologist, physician; at the end of fifty-six years of incredible activity, when facing the end, he appraised his life, and it hardly surprises us to learn that he found in its record nothing to regret.

HORATIO B. WILLIAMS
DEPARTMENT OF PHYSIOLOGY,
COLUMBIA UNIVERSITY, NEW YORK

THE INSTITUTE OF HUMAN RELATIONS AT YALE UNIVERSITY

WITH the opening of the academic year at Yale University, marked progress in the development of the Institute of Human Relations is reported. The institute is to be a center for research in biology, psychology and sociology. All members of the staff will also hold appointments in the fundamental departments of instruction, so that the institute will be closely knit to the university as a whole and will serve as a means of correlating the work in the various pure and applied fields of science dealing with human life. Its primary purpose is in fact the stimulation of cooperative research so that the barriers which have arbitrarily separated related disciplines may be broken down. It is believed that many impediments to progress in the understanding of human conduct may thus be removed. Through the close affiliation of the institute with the professional schools, such as medicine, law and religion, it is believed that the training of men in these fields may be broadened.

A number of university appointments bearing on the work of the institute have already been made. Dr. William Healy and Dr. Augusta F. Bronner will commence this year a study of the family factors in delinquency. In Boston, New Haven and Detroit, groups of families, members of which have been in contact with the juvenile courts, will provide the material for the study.

Dr. Edward C. Streeter, who has been appointed visiting professor of the history of medicine in the Yale School of Medicine, will take part in a broad study of medical organization. Dr. Walton H. Hamilton, of the Yale School of Law, will supervise the economic aspects of this study which has been authorized by the American Medical Association.

Dr. Edgar Van Norman Emery, former chief of the Los Angeles child

guidance clinic, has been appointed to the staff of the department of psychiatry and mental hygiene, and will have a particular interest in the work of mental hygiene in the college which was started some three years ago. Clark Leonard Hull, former director of the psychology laboratory at the University of Wisconsin, has been made professor of psychology.

A survey of European personnel in psychology and neurology was recently made by Dr. Milton C. Winternitz, dean of the Yale School of Medicine. Among the appointments which have followed is that of Dr. John F. Fulton, who is now at Oxford with Sir Charles Sherrington, world-renowned physiologist. Dr. Fulton will be associated with the institute in the field of neuro-physiology.

Construction has been commenced on the institute building which is to house the following already existing university units: Department of psychiatry and mental hygiene; division for research in economics, sociology and government; graduate division in psychology; child development research division. The staff in psychology includes, among others, Raymond Dodge, Arnold Gesell, Clark Wissler, Robert M. Yerkes and Arthur H. Ruggles.

The building is to cost $2,000,000, of which $500,000 has been given by the General Education Board and $1,500,000 by the Rockefeller Foundation. The following gifts have been made by the Rockefeller Foundation for the work of the institute: For the educational program in psychology, $50,000 a year for ten years; for the maintenance of patients in psychology, $50,000 a year for ten years. The Laura Spelman Rockefeller Memorial has given $150,000 a year for ten years for social science research, for psychology research and for child development research. The Commonwealth Fund has now provided $50,000 a year for the work in mental hygiene.

The Institute of Human Relations, with the Yale School of Medicine, the Yale School of Nursing, the New Haven Hospital and Dispensary, constitute what is termed the *Human Welfare Group.* For the development of this group a program requiring $15,500,000 was outlined last February, and $5,600,000 of this amount must still be obtained, according to reports from the university.

# THE SCIENTIFIC MONTHLY

FEBRUARY, 1930

KIM KURMAH, OR, WHAT ARE WE ABOUT?[1]

By Professor G. H. PARKER

HARVARD UNIVERSITY

WERE I to address you in the spirit of the "Systema Naturae" of 1758, I might say to each one of you, "Homo sapiens, subspecies naturae investigator americanus, race demonicensis." I would thereby recall to you through the specific part of your name the compliment that old father Linnaeus slyly passed to himself and to us all in designating us men of wisdom. Nor do I believe that he would object to my addition to his terminology, for are we not American naturalists, and residents, at least for the time being, of Des Moines? To this new-world domicile of the monk, for so I understand the ancient meaning of its name, we have come to partake of its refreshment, physical and intellectual. The dictionary tells us that the moines or monks are a company of men vowed to separation from the world, to poverty, to celibacy and to a religious life. Have we found them such? Yes and no. I shall not attempt to enlarge upon the fact that their separation from the world has made them more human than we who live in it. Nor shall I remark on the success with which their generosity covers what the dictionary is pleased to call poverty. So far as concerns their celibacy and their devotion to a religious life, delicacy and a deep consideration withhold me from comment. As a world within itself Des Moines is all-sufficient. Blessed have been the hours of our brief sojourn here. We carry with us from this spot happy remembrances and we trust that as worldlings we have brought to it no jot of contamination.

But to return to *Homo sapiens*. Are we as wise as the good old Linnaeus believed we should be? Wisdom is certainly attributed to us, but is it really ours? How many of us would attempt again even the doctor's examination, not to mention an I. Q. determination? A close friend of mine, after a severe illness, could get no word from his physician as to whether he was whole or broken. In despair he betook himself to a life-insurance company, underwent an examination, and was accepted. He did not insure, however, but paid his fee and went his way rejoicing. How many of us would invite a similar examination of our claims to wisdom? As one of the last surviving members of the rapidly disappearing School of Behaviorists, I beg of you in seeking the answer to this question to inspect with care certain of our reaction patterns. I do not refer to what may be called our nest activities, but rather to those performances that stamp us as *naturae investigatores americani*. When we are not on vacation we are known to exhibit in a highly specialized environment and before the young of our species a remarkable set of responses that the world at large calls teaching, and when we can gain the laboratory sanctum we indulge in another class of performances—mostly in great privacy—that have received the designation re-

[1] Presidential address read at the annual meeting of the American Society of Naturalists, Des Moines, Iowa, January, 1930.

search. These two reaction types afford to those who observe our behavior the chief body of evidence for calling us men of wisdom. Let us scrutinize them more closely, and first:

Teaching

Of teaching there are three kinds—by example, by the voice and by the printed page. How easy it would seem to select the words of truth from the past, print them in an inviting and acceptable form and place them in endless editions before the young. But how different is the real task! One text in science is scarcely out before another is jostling at its heels. Publishers strive to start the new volume with the impress of the new year. Everything must be up-to-date, and that date must be now. We seem to forget that the best things in science happened before A. D. 1930. Not that a recent discovery should be ignored, but much that is important in science is far from recent, yet calls for comment. The few best texts hold their own, not because they are so much up-to-date, but because they come down-to-date so well. The intensity of our interest in the present appears to have dulled our sense of the historical. To appreciate Aristotle, it is well to recall that the compound microscope first came into use a little after 1600 A. D.

In preparing our texts and papers do we strive to write so as to engage the interest of our readers? Most of us, I fear, do not. We are obsessed with the idea that the subject-matter of our particular science is so innately interesting that we have no call to pay attention to style. To us the form of written presentation counts for almost nothing. Consequently many a worthy pupil turns down our printed page and, like the lovers in the "Divine Comedy," reads no more that day. How many times did I meet the simple statement that the human body contains about 59 per cent. of water before I grasped this obvious fact, and how many of my pupils have read this declaration, only to forget it forthwith? It took Sir Arthur Shipley to catch the waning attention by the simple sentence, "Even the Archbishop of Canterbury comprises 59 per cent. of water." After I had read this passage I asked an English colleague why Sir Arthur had in this way singled out the archbishop, but he assured me that there was nothing associated with this worthy prelate that called for special comment, and that this dignitary had obviously been selected only to serve as an example of our species. We Americans with our "Wets" and "Drys" are perhaps not so fortunately supplied with telling personalities. Who would hazard on this point a declaration of the percentage composition of our dry President at the White House and of his recent wet opponent in New York?

Another custom that we have which makes our texts less inviting than they should be, if not actually repellent, is the impersonal way in which we treat our subjects. Science itself may be impersonal, but the discoveries of science are far from being so. No major scientific discovery has ever been made without involving a personal situation, and often a most interesting one. Who can read von Baer's account of his first view of the mammalian egg without a thrill of excitement? He began his search for this important structure in 1826, and he completed it successfully the following year. In his autobiography he records the physical strain and damage to health that he suffered from the long hours of microscopic work that this investigation cost him. "And so it happened," he says, "that in the course of a year, I shut myself up in my shell while the snow was still on the ground, and when I again ventured out to cross the garden wall only a hundred steps from me, I was astounded to find that the fields of rye were in the ear." This is the application and energy that brought to light the

mammalian egg, a demonstration that an ordinary student can now make in one of our laboratories in half an hour or so. Yet the first time it was done, it required long-sustained human effort. How slight is our record of such achievements!

In an otherwise admirable book on life published only a few years ago, novelists and poets are named galore, but scarcely a hint is given as to those whose work fills most of the pages. Without converting our scientific texts into historical ones, could we not to advantage make them somewhat more personal? Light in this direction is already dawning.

What has been said of teaching by the printed page applies almost equally to teaching by the spoken word, and yet there are important differences. In the lecture or in the informal talk, the teacher has the pupil down, so to speak, at least for a limited time. What are the momentary advantages in this situation? Chiefly, emphasis and accentuation. In a good talk topics should be treated by us as in a newspaper. Some should be in headlines, some in leading type; some should be stated in full and others in abstract. In brief, the whole situation should be given light and shade. Thus a picture may be sketched. But how often our outlines blur, our colors run, and the whole composition loses point! Who, then, can blame the novice for lack of interest, or even for falling asleep? Perhaps the real art on such occasions is to sleep in one's own lecture. I knew of but one instructor who succeeded at this trick. The class was not large, it was two o'clock in the afternoon, and the season, a warm spring. With interested eyes we watched the struggle between our beloved teacher and Morpheus. First one was on top and then the other, but the remarkable fact remained that the lecture went on. I confess that it was a very deliberate one, but it hung together, and in the end it was complete. We looked up to our professor as an unusual character, as in fact he was, for he had accomplished two things in one, a nap and a lecture. He was not what would be described as a hustler, but in this instance he had what might be called double-barreled efficiency. He has long since left us. Peace be to his ashes, for he was a most revered teacher. I can not, however, recommend the napping lecture habit. It is too dangerous a pastime, and to carry it off successfully calls for an ability almost equal to that of a genius.

If the ease-loving instructor has his pitfalls, so does the hyperkinetic one. High-strung and on the jump, like the proverbial flea he is never where you expect him. He deluges his hearers with statements meant to inform, but poured out at such a rate as to be unintelligible. I once looked into the note-book of a student who had been through an hour of such treatment. It revealed a succession of half-completed sentences concluding with the statement: "We now see that the frog's mesoderm regularly takes origin from the entoderm," to which was added the pious ejaculation, "Thank God!" How often, after such an experience, have we felt that we would have had our money's worth had half as much been offered us. Walt Whitman knew something of this feeling when he wrote for another brotherhood what might perfectly well apply to some of us.

When I heard the learn'd astronomer:
When the proofs, the figures, were ranged in columns before me;
When I was shown the charts and the diagrams, to add, divide, and measure them;
When I, sitting, heard the astronomer, where he lectured with much applause in the lecture room,
How soon, unaccountably, I became tired and sick:
Till rising and gliding out, I wandered off by myself,
In the mystical moist night air, and from time to time,
Look'd up in perfect silence at the stars.

May it be given us not thus to empty our lecture halls.

And now a word or so about teaching by example. If teaching by the printed page and by the voice are the mechanics of our occupation, teaching by example is the psychology of what we do. Nowhere else are relations so subtle and intricate as here, and nowhere else is comment or suggestion so uncertain. On the one hand, a pupil may imitate, at least so far as within him lies, every act of his beloved teacher, or on the other hand, in utter condemnation he may do exactly the reverse. Examples of both courses are known to us all. Not many years ago two young men developed such a striking resemblance to their mentor that they were commonly known as the "blank" twins; the term "blank" standing for their superior's name and not for the usual expletive. I once heard a distinguished zoologist declare that his more distinguished teacher and predecessor had been to him an example of everything he should not be. How marvelous and unaccountable are our natures!

On the whole I am inclined to lay more stress on the principle of contrariness than on that of imitation. In my experience the imitators yield ultimately less admirable products than their opposites. Contrariness in students is in my opinion of great pedagogic significance. The pupil, like the child, is greatly excited over a taboo. I believe the surest way to get books read is to cover them with brown paper and hide them on a shelf, or to lock up the set in a case with glass doors, and mark them, "Not to be read by students." I well remember in my early days as an assistant in the laboratory a text on anatomy, from which, through vandalism, two pages had been removed. It is not an exaggeration to say that within a week half the students in the class had looked up the volume elsewhere and inspected and read the missing pages. They believed these pages to have been removed because of objectionable matter. So prone are we to reverse regulations.

Since this habit of mind, rather than that of imitation, seems to be a mark of budding genius, I suggest that we as teachers cultivate it in our pupils by assuming in ourselves a number of minor vices, the opposite virtues of which we hold to be beneficial for those whom we teach. I believe I have never before advocated any vice, but as I mature I am forced to admit that a really virtuous world can show up well only if it includes a few examples of vice by way of contrast. And now a few words about our second reaction type.

Research

If what we impart in knowledge and practice is the trunk and branch of the tree, what we deliver by research is the living twig and shoot. Just as the growing tips are essential to the life of the tree, so is research to the vitality of science. Every really first-class teacher does research. To quote Sewell, with a slight change of tense, "No upward growth can be hoped for except from teachers who can produce knowledge as well as impart it." This statement is now universally admitted, and it behooves us in our adjustments with the various organizations with which we are associated to insist upon proper provision and time for this activity. It is a short-sighted policy for any institution of higher learning to impose such an amount of routine on any of its scientific staff that research becomes impossible for them. One might as well cut off their food or sleep and expect them still to teach successfully. It is a fortunate omen that in many of our best institutions the choice for staff appointments turns on research ability. An able investigator may not always be the most skilful teacher, but he is the safest gamble for such a high appointment.

Science is in no sense mystical. It is based on clear, sure vision and it has developed in those races that look thus on the universe. It is essentially an occidental product that is gradually perme-

ating the whole earth. Of European origin, it betook itself with the discoverers to the New World. In the Orient it was quickly accepted by Japan, and there is every reason to believe that notwithstanding the national upheavals in progress, it is making rapid strides in China. It moves more slowly in India, probably because the magician and the necromancer have so strong a hold upon this people. The truths of science do not emerge from some deep recess of the human soul, but are the results of direct observation. No less a thinker than Leonardo da Vinci, who knew life in its fulness, declared that "all knowledge is vain and erroneous except that brought into the world by sense perception." Truth thus brought forth has no restriction. In the words of Sir Humphry Davy: "Science, like that nature to which it belongs, is neither limited in time nor space; it belongs to the world and is of no country and no age." And to quote from the biological side, von Baer has said, "Die Wissenschaft ist ewig in ihrem Quell, unermesslich in ihrem Umfange, endlos in ihrer Aufgabe, unerreichbar in ihrem Ziele." This is the dominion of scientific research. In this great field we work. No other realm of human endeavor can offer equal possibilities.

Do we cultivate this field as we should? Are we diligent in effort, intellectually honest, not only with others but with ourselves? Are we scrupulously careful to be as free as possible from error and unmistakable in statement? If so, we have little to concern us, but, as every one knows, the pitfalls are many. Even the choice of a title for a discourse or a publication is no simple matter. I recall that once in my youth I was asked to prepare a paper on some aspect of the stem of the vertebrate brain. I chose as a title, "Diencephalon, Mesencephalon and Metencephalon," and I was awakened from my slumbers under this mass of verbiage by a comment in the program of the proposed meeting to the effect that notwithstanding its title my paper would be given in English. Nor can I forget my unsuccessful attempt at this early stage to dissuade a fellow worker in our laboratory from heading his address, "The Chondrocranium of the Blue-tailed Skink." As I now look back through the years, this title still rings forth with a certain poetic rhythm such as one hears in few like efforts. Another member of the laboratory, a moderate purist, insisted once on publishing on the brachial and lumbosacral "plexi" of a certain animal. Hardly had the paper come from the press when to our mutual dismay we read from the pen of a real purist the crushing comment that "plexus" was not a second, but a fourth declension noun, and that its singular and plural forms were the same. I made a hasty survey of my early steps in classical education, only to conclude that at that time of life I was probably more interested in "puella, puellae, puellae, puellam" than in the more advanced declensions. But classical language must have its place, even in the titles of our papers, which reminds me that in choosing a designation for the present effort, I have attempted to please both sides. As you can see, one half the title of this address is as vitally direct and simple as words of about one syllable can make it. The other half forces Latin and Greek to look fresh and blooming, for it comes from a source as dry as dust. "Kim Kurmaḥ" is Sanskrit for "What are we about?"

Speaking of titles reminds me of the body of the text. How blissful life would be if research without further ado would transform itself into the orderly written page. But most of us, I believe, suffer from the pains of composition. Clearness and brevity are the essentials of scientific writing. But whether we use capitals, semicolons, colons or even sentences sparsely or freely is not important. A legal acquaintance not long ago told me that in formal documents now-

adays the only admissible punctuation mark is the period, and considering the use of the capital and the break in the line, he doubted if that sign is really necessary. Perhaps the best rule in punctuation is that once employed by an American wit, who left out all signs in the body of his laugh-provoking composition and concluded it with a couple of pages of colons, commas and the like, with a note to the effect that each reader might distribute them to suit his own fancy.

Even so well established an element in composition as the sentence may come in for its share of revision. A sentence, as I understand it, is such an amount of writing as can be read conveniently in a breath. Sentence structure implies reading aloud, and the sentence itself may be regarded as the unit in a respiratory form of composition. But how many scientific papers are composed to be read aloud? Fortunately or unfortunately, almost none. We write to be read in the depths of silence. Since the flow of thought is continuous, it has sometimes occurred to me that we could better imitate the clarity and continuity of this flow by writing our words in uninterrupted series than by breaking them into sentences. The unpunctuated stream of text that flows over some thirty-five pages of a part of Joyce's new Odyssey may be a worthy example to those who would change language from a respiratory to a cephalic level. But what a frightful tumult this change would cause in the breast of a conservative nature, who, like poor Beckmesser of the stage, loves form so deeply that his best efforts yield nothing else. Why use even a parsable sentence if it conveys almost no idea? Yet some of us delight in talking for conversation.

But enough of trivialities. We must be serious. What in this inviting and almost unlimited field of research are we really about? And here, in accordance with our tastes, we mutually part company and scatter in many directions. Some seek to describe all living plants and animals and to show, as in a Sears-Roebuck catalogue, pictured examples of each kind. To them the temple of their devotions is the museum, once the home of the nine Muses, as attendents on Apollo, and now a huge catacomb of mummified nature. Here the world of living things is epitomized, that we may understand at a glance what a gigantic task beset our ancient progenitor Noah in the days of the great flood.

Others there are who seek to follow the wanderings of animals and all that they have done in transporting themselves and others from place to place. What a strange glimpse into nature they give us! I once asked a budding student of history who had discovered America and received the immediate reply, "Columbus." My look of doubt provoked the retort, "But you do not believe in Leif Ericson as the real discoverer, do you?" No, surely not. America was discovered by an Oriental horde which made its way from the Old World through the Bering Sea connections into the New World, to establish there that race whose members sat on the shore of San Salvador and watched with open-eyed wonder as Columbus rediscovered this land. Over the bridge from Siberia to Alaska and back again surged the animal life of two hemispheres, and yet our school books still declare for Columbus. Wonderful as his achievement was, an Oriental preceded him. This is one of the lessons taught us by naturalists who study the wanderings of animals.

Then, too, there are those who seek glory at the scalpel's point—the anatomists, the morphologists, the cytologists, the embryologists and a host of other "ists" who crowd institutions proudly called laboratories, as if these abodes had a monopoly on work. Some of these delvers find much in the larger animals, in what Shylock in the play calls the "harmless, necessary, cat." Others at-

tempt to expose to view the inmost parts of creatures so small that scores of them might dance on the head of a pin. These workers use microscopes, microtomes, micro-apparatus of all kinds and an infinite array of special fixatives, preservatives, stains and the like, all calculated to catch and hold the evanescent phases of life. But what they study in the end is for the most part preserved, often as perfectly as an ant in amber, but very, very dead. Does it really represent life? Who knows? Many believe so, and with such vehemence that their credo has already been written, beginning, "I believe in cytoplasm, in the chromosome, in microsomes and centrosomes, and in neurofibrillae, etc." But are the followers of this faith justified in the transfers that they make from the dead to the quick? Are we sure that what we see in a beautifully stained preparation is really in the living tissue? In my opinion we must heed von Uexküll's warning: "We have reckoned without our host, and the host's name is Life."

It is an easy transition from the field last mentioned to that of genetics. How do we as human beings come to be what we are, and how do all other living things reach their proper goals? Strangest of processes! That a jot of living substance from a living creature should grow into a bug, a cow, a whale or a man, according to its source! Such, however, is the fact. To keep these processes of growth running true that the creatures may reach their proper destinations, we have imagined a host of demons, the determiners, the biophores, the genes, whose special business it is to see that the goods are delivered. From our very earliest infancy they direct our course of growth, or if in this course two avenues are open to us, they see that we do not choose a third. What lack of confidence this oversight implies! Is not the growing substance capable of managing its own affairs? May it not increase in accordance with its own nature? Why must these controlling agents be superimposed on a process that may really be scheduled to run itself? The redundancy reminds one of the Irishman who begged his neighbor to lend him the loan of his knife. Why not dispense with all this governing superstructure and let protoplasm do its own work? No chemist calls on determiners to make the oxygen of the air unite with hydrogen to form water. These things take care of themselves, and whatever it may be that brings them to pass, it adds nothing to our understanding of the process to superimpose an assumed control. Of course, organic growth is enormously complex as compared with the formation of water, but who bothers about a determiner of the weather, for instance? This natural change runs its own course, grows, so to speak, in its own way, and yet is as law-abiding as any organism. Why not give protoplasm an equal chance?

And so we might go on from clan to clan, to ecologists, to parasitologists, to physiologists, to pathologists, to evolutionists and to a host of others, all of whom seek answers to their own questions in their own way. Were we to ask these workers one and all what general problem interested them most, I suspect they might agree in desiring to know how it is that we moving, sentient, thinking, dreaming beings come from aggregates of protons and electrons operating under quanta regulations. This question was once answered by a clear-headed Catholic, who declared that at a given point in the course of our evolution from the lower orders of creation the Almighty infused a soul into the creature, and from that moment on it was what we are, and worth saving. This implanting of the soul, my Catholic friend said, is what some biologists might call a mutation, but what a Catholic would call a miracle. The difference between our views, he maintained, was paper-thin, almost a matter of phrasing.

But frankly I do not believe the question can be disposed of so easily.

I once read that Sir Isaac Newton had expressed the hope that in time the activities of living things would be understood in the same simple way that he had been able to understand through the universal principle of gravitation, the movements of the heavenly bodies. What biologist has not entertained in one form or another this very hope, but are we justified in such an aspiration? Eddington, in his recent book on "The Nature of the Physical World," tells us that one of the most remarkable conceptions entertained by modern science is that of the almost vacuous nature of solid bodies. Each of us is made of atoms, no longer the miniature billiard balls of the older physicists, but aggregates of protons and electrons probably arranged like minute solar systems. Such being the case, an atom is vastly more empty space than solid substance, and, to follow Eddington, if our bodies were reduced to real solidity by the condensation of our atomic structure, we should go down to a pinhead in size. In this way our too, too solid flesh would melt and shrink to a mere speck. Will this speck of real substance suffice for what I am? The idea is novel, to say the least.

But to return to Newton. His conclusions, and with them his hopes, appear to need some modification. It seems that the core of the universe is not so lucidly understandable as he thought. The modern physicist, for example, has his doubts about the absolute application of the idea of cause and effect in atomic and subatomic relations. In the interaction of colliding quanta and electrons, it appears no longer possible to prescribe with perfect accuracy the courses taken by the separating elements. We are compelled to admit, even in the most rigid theoretic consideration of the subject, a minute angle within which anything may happen. These ultra uncertainties are always present, yet because of their excessive smallness they have no practical significance for us, nor for other bodies of our size. Nevertheless, they must be regarded as indicative of a fundamental, though extremely minute, flaw in the Newtonian conception. They imply a radical modification of this view in line with that advanced by Einstein. They are incorporated in what is termed Heisenberg's principle of uncertainty.

If this principle rules in the very heart of mechanics, why trouble ourselves about the uncertainties so characteristic of the performances of organisms? But the Heisenberg principle is only of ultra-atomic application, and it is therefore clear, as Bridgman has pointed out, that biologists are not justified in carrying it over to those massive types of response associated with the bodies of living things. Undoubtedly the electrons and quanta of the human body exhibit all that they should in conformity with the principle of uncertainty, but such modifications are so infinitely small compared with our bulk that we see nothing of them. Their effect is like that of heat in changing the volume of a body before accurate measurements of length were possible. The outcome of Heisenberg's principle, though present in us, is not sensed by us. It is not for a moment to be supposed that if we fall from a height we do not in every reasonable way exhibit the acceleration of gravitation as we descend to the earth. Nor are we to believe that the main outline of the chemistry of our bodies has not already been correctly described. Here again we know full well that our bodies follow classical models. To be sure, we are units whose integration is unusually extreme, and we know that our dissolution is accompanied by a loss of something which, as in the separation of a verse into its words or a melody into its notes, is nowhere found among the independent elements. This idea,

the burden of modern emergent evolution, is recognized by all. But this way of viewing organisms does not exclude the opinion according to which the living animal continually reveals peculiarities seen in the most lifeless material. We appear to have arisen exclusively from such material; we exhibit its properties, but we have much more in us than these simple properties, though not so much as some would have us believe.

Entelechies, mnemes, élans vitales, and the like, have had their days, for, notwithstanding the insistence of Driesch, Semon, Bergson and others, we are not as yet obliged to assume these vitalistic elements in our efforts to understand living matter, any more than we are called upon to accept for biology the limitations of classical chemistry and physics. No student of the problem can fail to see that chemistry and physics are growing subjects, whose methods and conclusions are bound in the course of time to exhibit ever-advancing changes. Their growth will force them more and more to invade the field of biology, as in fact they are already doing. Here they will meet with problems peculiar to this science, and their attack upon these problems will modify their conclusions and outlook as much as it will illuminate those of biology. It is impossible to predict what, in the whirligig of time, the outcome will be. Will the inorganic sciences absorb biology, or will biology absorb them? Possibly the type of union, if it occurs, will be more in the nature of fertilization than absorption, and a new science will be born. But whatever may transpire, one problem in this general field is bound to loom large, and that is the problem of organization. How do the parts in larger or smaller units interact? What makes integration possible? This is as much a problem in ultra-atomic affairs as in organisms or in stellar bodies, and it is undoubtedly the general problem that occupied Newton's mind when he expressed the hope that the activities of organisms would be understood in the same way in which the movements of the heavenly bodies had been elucidated.

At sight of this general problem, many biologists are smitten with one or other of two strange phobias. There are some who, on hearing of analysis and disintegration, fall into paroxysms of fear lest the most precious things in life be lost, and there are others who are compelled to close their eyes in the presence of living things, lest they see complications beyond their present ken. It is difficult to say which phobia is the worse. The cure is that practiced on four-legged nature—take off the blinders and lead the afflicted creature near enough to the object of his fear that he may see its real innocuousness. The analytic process in biology is a perfectly innocent procedure that has shown us that down to the very bottom of our natures we are part and parcel of the universe around us. This is no small accomplishment, but as a result of such success we must not close our eyes to the fact that living substance may be so organized that to understand it in its totality requires a consideration of its united relations as an intact whole. While many of us work in analytic ways, it behooves us to keep our eyes continually open to those integrated aspects of nature which we recognize as individuals of higher or lower order and which exemplify the complications of life. It is in this direction that we are likely to meet with scientific novelties of the first order. The importance of maintaining this attitude of mind has been clearly set forth by Bridgman, who in his recent volume on the "Logic of Modern Physics" has declared that "it is difficult to conceive of anything more scientifically bigoted than to postulate that all possible experience conforms to the same type as that with which we are already familiar." And after we have done our best in giving our small contributions to the solution of this major problem, we can do little more than follow the rule of one

of our foremost countrymen, Benjamin Franklin, who, in speaking of his scientific beliefs, declared: "I leave them to take their chances in the world. If they are right, truth and experience will support them. If wrong, they ought to be refuted and rejected."

The effect of what we as naturalists are about may appear to have only a remote bearing on the civilization of our day. Who cares how many species of Strongylocentrotus there are in the sea? But we must remember that precisely this kind of knowledge about mosquitoes, about their distribution and their life histories made possible the building of the Panama Canal. Most of us are retiring and modest creatures, and as a result we are given to underestimating our own performances. It is only from others that we may expect a generous appraisal of our work. In an address given a few years ago at the Washington meeting of the American Association for the Advancement of Science, the then Secretary of State, Mr. Hughes, declared, in speaking of scientific workers: "If civilization is to advance, it will be your doing, and the best we can hope for governments is that they will not stand too much in your way." And on the same occasion, Mr. Coolidge, at that time President of the United States, said: "We trust ourselves to you with some doubts as to what you may finally do with us and to us, but at least with firm conviction that your activities will save life from becoming monotonous. And besides, we realize that if we did not give you our confidence, you would go ahead without it." These statements indicate the respect, not to say the awe, with which we are regarded even in high places. But what, I am sure, we most wish for is not simply to influence those in supreme stations, but to spread science throughout the world, not as a body of fact, but as a way of life. As Findley said a few years ago: "For the community as a whole, it is not the acquisition of a knowledge of the facts of science, but the becoming imbued with the spirit of science that is of chief importance." This life is full of questions that range from those of international procedure to such as stand between parent and child. The answers to such questions may be passionate, with war and undue chastisement as the result. The scientific spirit does not seek a passionate answer. It seeks one based on a deliberate and impartial consideration of the circumstances. Thus truth is attained, and decisions based upon truth have lasting strength. A civilization that seeks in this way to resolve its difficulties, large or small, is permeated with the scientific spirit, and to infuse this spirit into the world is one of the things that we should be about.

WHY THE 200-INCH TELESCOPE?

By Dr. ELIHU THOMSON

THE GENERAL ELECTRIC COMPANY

THE object of the society which I now address, namely, the American Philosophical Society, the oldest society of the kind in America, which has existed for about two hundred years, is to coordinate knowledge in all the different fields, to seek expansion of that knowledge in new directions and to assist in the progress obtained by improving the facilities, not only in the study of science but also in the humanities and in all phases of human effort, leading to a better understanding of our life on this earth. It is here that the leaders in investigation, the explorers, the advance thinkers, may present their results and have them recorded. This, indeed, is philosophy in its broadest sense.

As civilization spreads, as populations increase, there comes, naturally, the need of a widened sphere of activity, more resources to conserve the recorded results of the work of the eminent men and to make adequate provision for the inevitable expansion of the work in the present and the future.

The society is fortunate, at this time, in having started on a period of expansion which will eventuate, we hope, in realizing the objects which I have just pointed out. Fortunately, too, from Franklin's time, the American Philosophical Society has been uninterruptedly active and has attracted to its meetings and programs leaders of thought from all parts of our great and growing nation, as well as from abroad. Its limited quarters are now outgrown, and it must seek its expansion elsewhere than in this hall. I need not dwell on the details of this enlarged program, which have been carefully worked upon by the officers of the society and which it is earnestly hoped can be carried through successfully.

My present task is quite different, although, in a sense, there is an analogy. The astronomers have greatly increased their facilities, extended their observations and have approached the need for more effectual instrumental equipment in the exploration of the great universe in which we exist. I may quote here a paragraph from an article which was published in *Harper's Magazine* for November, 1929. It was from the pen of Dr. George Ellery Hale, honorary director of the Mount Wilson Observatory, near Pasadena. He begins his text with these words:

> Astronomers, like other men, spend most of their lives in hard and often tedious routine work. They are, however, sometimes fortunate enough to take part in a great adventure, and it is of such an adventure that I am now writing.

The title of the article of which the quotation just made is the opening paragraph is "Building the 200-inch Telescope." I commend to any one who is interested the reading of that article, because Dr. Hale has presented in a brief form, from the astronomers' standpoint, the reasons for and the advantages to accrue from the possession of the proposed giant instrument.

It will not be my function, in dealing with the subject of the 200-inch telescope, to treat it as an astronomer, nor shall I treat it as a designer of a huge instrument, surpassing in magnitude anything before undertaken, would treat it. I shall not compare it with a battleship in cost, although it will involve a large expenditure, but what I have to say

will concern the heart and soul of the great instrument, so to speak, namely, the mirror which reflects the light from the distant celestial objects and brings it either to the photographic plate or to the human eye.

There exists at the Mount Wilson Observatory, near Pasadena, the largest telescopic instrument in the world, usually spoken of as the 100-inch. The mirror, which, of course, is the most important part of the instrument, is made of a great block or disk of glass, about one hundred inches in diameter and about thirteen inches thick, and this block weighs, I think, about four or five tons. It took a long time to melt the glass; indeed, it was difficult to find any glass-maker to undertake to make that glass disk, there were so many uncertainties. Three large pots of glass were poured into a mould and cooled through months of gradual loss of heat so as to anneal the glass and prevent its going to pieces by uneven contraction and expansion. But that was only a portion of the difficulty. Once obtained, the glass had to be worked into the form of a disk having a slightly concave surface, and this surface had to be shaped with the greatest accuracy to the form of what is known as a paraboloid of revolution, so that the light of a distant star, for example, would be brought to a single point, or as near to a point as possible. The light of a star falls on every part of the surface of the mirror one hundred inches across and from that face must be reflected so as to reach a focus many feet away, all parts of the extended surface cooperating to direct the light to that distant focal point. The least divergence from the proper path of the light ray from any part of the surface is destructive; the image is imperfect, blurred, more or less indistinct; the fine definition, as it is termed, is lost.

I saw the 100-inch mirror under preparation at Pasadena by Dr. George W. Ritchey. The grinding and polishing is nothing as compared with the time it takes to figure or give final exact shape to the mirror surface, that is, to give to it its final form within a few millionths of an inch. This is to say that the accuracy of the surface must be exceedingly great, inconceivably great for most people to visualize. When the surface is being formed by polishing it by a gently moving polisher, the glass is slightly heated and distorted. This is enough to make it necessary to stop the work for the day and put the mirror to bed, so to speak, under five inches or more of felt covering until the next day.

The next day the first operation is to uncover it and make tests by rays of light and optical means as to its form in different parts or zones, as they are called. These tests completed, the polishing goes on with the greatest care not to overrun or spoil the work already done, until at last, after about two years of this process with the 100-inch, the desired figure or shape was attained, be it remembered, not by grinding, not because one polishes the surface, but by polishing in just those places and to just that extent as will remove a very small amount of the glass and give it the paraboloidal final figure. Thus arose into being the present 100-inch mirror, the largest in the world and the basis for the largest existing telescope.

Popularly, one might imagine that the making of the mirror itself completes the work, but it does not. The mirror has then to be mounted in a balanced position so that it is not distorted by changing its position. This involves an elaborate scheme in itself. It has to be mounted so as to be turned in any direction facing the different parts of the heavens without being bent or even slightly distorted; it has to have a very thin coat of silver deposited on its front surface, because it is not like the ordinary looking-glass mirrors; one does not

look through it, but at it. The light falls on its front surface and is reflected from the exceedingly thin, polished film of silver which has been deposited on that front surface by chemical means. But that is not all, by any means; there is a great deal more. Such a mirror, however perfect in its make-up, its construction, its mounting and its silvering, is still subject to distortion whenever the temperature of the air around it changes. The face and edges of the mirror naturally change their temperature more rapidly than the body, and glass being a substance expanding by heat, the change of even a very few degrees in one part of the mirror in relation to another part practically destroys the accuracy of its reflection and therefore the accuracy of the images which man is seeking to examine visually or to photograph. So much so is this the case that there always must be a consideration of the coming night as to temperature, and an effort is made to guess ahead of time what that temperature may be and means are provided for giving the mirror the temperature which may have been assumed—mistakenly, of course, in many instances.

I am told that the 100-inch glass mirror is rarely used with its full aperture or with a full opening or full face (the 100-inch circle) but its edge is often cut down more or less so as to lessen its effectual size, according to the sharpness of the images.

It is difficult, indeed, to convey in a few words the necessity for exceeding accuracy of shape or figure of the surfaces of these mirrors and to make it understood how little a disturbance will throw them off: or make them ineffective for the work for which they are designed. There is a number of fairly large glass mirrors in existence in the astronomical observatories of the world, but they all suffer from the same disadvantages of glass expansion which I have tried, in as brief as possible a way, to point out.

It is now about thirty years since I made the first experiment, comparing a small slab of fused quartz, or fused silica, with a similar slab of glass, as preliminary to further work. I formed on each of these a slightly concave surface, and then used well-known optical tests to show whether the figure was maintained under different conditions. The experiment was, naturally, imperfect, but I felt sure of the result. On having the two mounted so that I could have a distinct and clear image of a small artificial star or point of light when used with an eye-piece as a telescope is used, I found that by instantaneous application of a moderate heat or a small flame on the back of the glass slab, the image went immediately all to pieces, as we may say; that is, it scattered, all definition was lost. A similar treatment of the quartz slab showed very little change, and not until the back of the quartz had become quite hot was there a semblance of the disturbance that occurred with the glass.

This experiment, modest as it was, convinced me that there was one material suitable for the making of astronomical reflectors that would avoid many of the difficulties of construction and operation inherent in the glass-mirror telescope. I have kept the matter in mind, but only in recent years have I been able to extend the work to include mirrors of such size as would be actually useful in astronomical work. Dr. George E. Hale, himself, was one of the first to ask for blocks of fused quartz from which mirrors could be made.

What, then, is our task at the Thomson Research Laboratory at Lynn, of which I am director? This is a laboratory of the General Electric Company used for research. Is our task to provide the funds for the work? No. They are provided by certain funds which ex-

ist and which are devoted to this purpose. Is our task, then, to design and build the telescope structure of steel framing—admirable and huge mechanism as it will be? No, we have not that task; others will take care of that part of it. Then what is our task? The answer is simple; it is to provide the mirror, and this mirror body will have to include in it two new pioneer characteristics. The first is its great size, far beyond anything before contemplated. It will be twice the diameter of the existing 100-inch mirror at Mount Wilson and will, therefore, have four times the surface and be very much thicker. It may be six to eight times the weight of the glass mirror at Mount Wilson, or say twenty-five to thirty tons in weight. The second and more important pioneer character is in the material used for such a mirror. It is not of metal, as the great Lord Ross instrument was, speculum metal, six feet in diameter; it is not to be of glass, as in the most recently constructed instruments of large size. Glass, as I have pointed out, gives great difficulties. It is very difficult to melt the glass, get it uniform and cast it, with the subsequent slow cooling and annealing through months of time to avoid its splitting or fracturing by uneven cooling or having within it uneven structure. It is far more difficult to shape glass to the accurate figure demanded, as the building of the 100-inch mirror showed clearly. It is even difficult to use, on account of the deformity it undergoes by changes of external temperature, disturbing the direction of the light reflected from parts of its surface and spoiling its performance.

No, it is not glass that we shall use, but fused silica, or melted quartz, melted in an electric furnace at between 1,700 and 1,800 degrees Centigrade, which means more than 3,000 degrees Fahrenheit, or about the melting-point of platinum, a metal difficult to melt, as is well known, and which does not melt in ordinary flames or furnaces. The method we shall use, which we are using, in fact, on a small scale with great success, is, in general terms, one devised quite a number of years ago, and which consists in first melting a mass of good clean quartz sand in a circular mold in an electric furnace and obtaining thereby a disk or thick slab of melted quartz sand. This is, indeed, fused quartz, but full of tiny bubbles, which tend to make it lighter, but the melted sand has all the desirable properties of the solid fused quartz itself.

Now, what is the most striking and important of those desirable properties? Simply this, that it is a rigid hard material, almost expansionless by change of temperature. A bar of it a meter long, or a little over a yard long, if raised from ordinary room temperature through 1,000 degrees Centigrade, or about 1,800 degrees Fahrenheit (a very bright heat and one which is very near the melting-point of gold), expands only a half a millimeter, or about one-fiftieth of an inch. Considering this great range of 1,800 degrees Fahrenheit, it can well be understood that under ordinary temperature changes fused quartz practically does not expand or contract. It retains its dimensions.

Now if a mirror is made of such material it retains its dimensions and does not bother the worker in either producing it or using it. There is not the long task of polishing it and letting it cool between the efforts from day to day.

But I have spoken only of the foundation or base body of the mirror. I have not said anything about the second stage in its production. This comparatively rough, bubble-filled mass of melted sand, which is the underlying disk, has to be provided with a surface layer, more or less thick, of clear glass-like fused quartz, or silica glass. It will

have the same general properties, so far as expansion goes, and, therefore, will suit the purpose very well united to the sand backing. The first efforts were made by melting on to the fused sand backing slabs of clear quartz made in a different way, and the results were fairly successful. Fair mirrors could be made in that way, but at the suggestion of one of our skilled workers an experiment was made of feeding into an oxy-hydrogen blowpipe flame granulated or finely powdered crystal quartz (rock crystal) of high quality, and immediately it was found that a coating of clear quartz could thus be deposited upon any other piece of quartz. When oxygen and hydrogen are burned together in a jet, the temperature of the flame is high enough to fuse or melt silica, or quartz. By raining down through such a flame, the granulated crystal quartz is received on a surface much as ice deposits in clear layers on objects during a sleet-storm. In illustration I often use the analogy, only adding that ours is a high temperature sleet storm, with quartz instead of ice deposited in clear layers.

Extending this to a mirror, it was found that under proper precautions of temperature, the surface might be glazed with clear fused silica to any ordinary desired thickness by the simple process of introducing high-grade silica into a flame of such temperature as will melt readily the particles of silica as they pass through it towards the surface which receives it. In this case, of course, it is the surface of the mirror to be, as composed of the fused sand backing, which in the way I have outlined is covered with a layer of beautiful, clear, transparent fused quartz. When I speak of fused quartz or fused silica or silica glass, the same material is meant; the terms are used interchangeably.

It has taken considerable effort and time, and some money, to arrive at this stage in the operation, but the results are justifying themselves right along, and were it not so I should not have been ready or willing to tell you of the progress towards the making of the 200-inch mirror. We now feel that our task is indeed an enlargement of the scale of our operations. We do not, however, minimize the obstacles which will have to be overcome in enlarging to the great scale on which we must work when producing the 200-inch mirror. It is a gigantic thing in itself, but such a gift to science is a prize that is worth working for.

It has, of course, been necessary in doing this work and carrying it along, and the necessity will continue to the end of the accomplishment, that competent, enthusiastic coadjutors shall exist to take care of the very varied things which present themselves. They must, indeed, be both competent and enthusiastic. The work has just begun, and mirror blanks suitable for use in astronomical telescopes up to about two feet in diameter are produced and producible. These have all the desirable qualities which, of course, will be those of the great mirror. We can not speak of taking only months to produce the large mirror; we must speak of years. It may be two or three years before the large mirror is turned out, but every product of our work is itself an acquisition for astronomy, whether it be two-feet, three-feet, five-feet, six-feet mirrors, and we will go to our goal by steps. Every one of these interim products will be a useful and desirable thing for the astronomer; in fact, the construction of the 200-inch mirror involves the production of at least two or three others of less size to be used with it, in several combinations.

The process of actually shaping, the grinding, polishing and figuring of these

quartz mirrors, is practically the same as has been used in the making of the glass mirrors hitherto, and will be done probably at Pasadena under the care of the Mount Wilson Observatory optical staff, but with the great advantage that the work does not have to stop for equalization of temperature in the mass of the mirror as with glass, but can go on steadily, uninterruptedly, occupying days instead of years, and experience shows us that the material leads itself more readily than glass to the work of the optician.

The mounting and use of the great mirror will be the same, except for a great enlargement of scale, as they would be with a glass mirror, but there will not be the disadvantage of changes of temperature disturbing the accuracy of the work or its possibility. The fearsome process of using the sun itself as the object of investigation, for example, will not trouble with a mirror of fused quartz, as it would with a glass mirror. It is, of course, necessary to establish such an instrument in the best or steadiest air that can be found, little subject to currents of different temperature which disturb the passage of the light to and from the mirror in the atmosphere itself. Proper sites are even now being sought for the mounting of the great instrument.

The mirror blank itself will probably be made at the River Works of the General Electric Company at West Lynn, or nearby, and I wish to mention here the fact that the undertaking is carried on at the works of the General Electric Company without any idea of profit, but merely at the cost of labor and material, and a free gift is made by that company to the enterprise, of the engineering skill and existing laboratory equipment useful to the attainment of the end in view.

Naturally, the placing of the giant instrument is a problem in itself, but one which we can leave to the astronomers. We can leave also to the astronomers a description of what may be expected from the use of the giant mirror in the completed telescope, a great engineering structure itself, except to say in general that its light-gathering power will be probably not less than four times that of the 100-inch, but on account of the greater convenience this factor will undoubtedly be increased, as it can probably, in good air, be used without diaphragming down. Four times more light with equal accuracy means that the distance of reach of exploration is increased twice, which means that our visible universe is thus increased 2 x 2 x 2, or the cube, or eight times. If the effective light-gathering power be in still greater proportion, as is probable, then we have the universe further increased, but this, of course, is not alone the meaning or object of the instrument.

Every problem which is present with the astronomer to-day will, with the superb instrument, be more easily reckoned with. Its greater capacity for gathering light makes it easier to use higher magnifications if the image is accurate. It may, therefore, lead to our more complete knowledge of the planets which belong to our own system and assist greatly in the investigation of other heavenly objects which appear in our sky. It may help to solve some of the problems connected with that most interesting neighbor of ours, the planet Mars, about which we can form hypotheses but with little chance, thus far, of confirming or denying their validity. The major advantage may be summed up in the term "greater and more accurate space penetration."

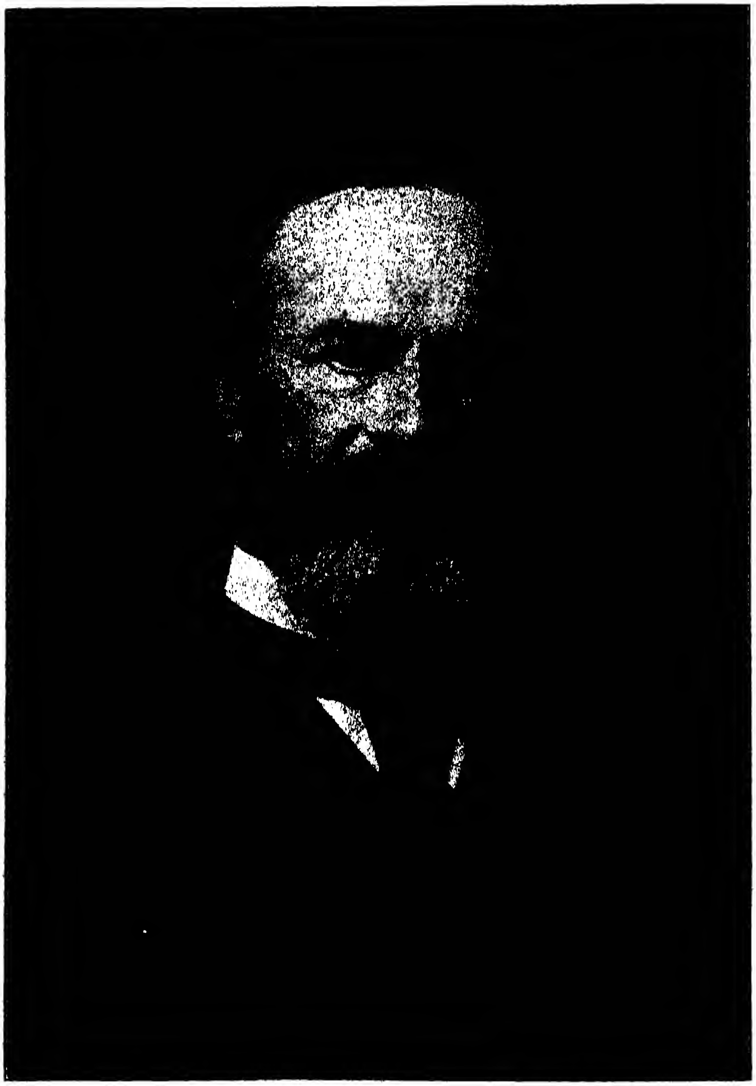
I can not close this statement without paying a tribute to our laboratory staff, who so far have borne the burden "and the heat of the day," so to speak, in the development which has so far progressed.

At the head of this staff is Mr. A. L. Ellis, assistant director of the laboratory, who has been most indefatigable in carrying on the development. They have all done their part, and have done it most enthusiastically and productively. I should like to enumerate them and credit to them their different contributions.

I will close this statement with a quotation from an article which I contributed to the New York *Sun* on "Electricity During the Nineteenth Century," which was published early in 1901. On the last of the twenty-five pages, the article concludes with this statement:

> The hands of man are strengthened by the control of mighty forces. His electric lines traverse the mountain passes as well as the plains. His electric railway scales the Jungfrau. But he still spends his best effort, and has always done so, in the construction and equipment of his engines of destruction, and now exhausts the mines of the world of valuable metals for ships of war, whose ultimate goal is the bottom of the sea. Perhaps all this is necessary now, and, if so, well. But if a fraction of the vast expenditure entailed were turned to the encouragement of advance in the arts and employments of peace in the coming century, can it be doubted that, at the close, the nineteenth century might come to be regarded, in spite of its achievements, as a rather wasteful, semibarbarous transition period?

And I might add now, "Has it been any better in the first quarter of the twentieth century?"



Wm James

PSYCHOLOGY IN AMERICA[1]

By J. McKEEN CATTELL

FORMERLY PROFESSOR OF PSYCHOLOGY IN THE UNIVERSITY OF PENNSYLVANIA AND COLUMBIA UNIVERSITY

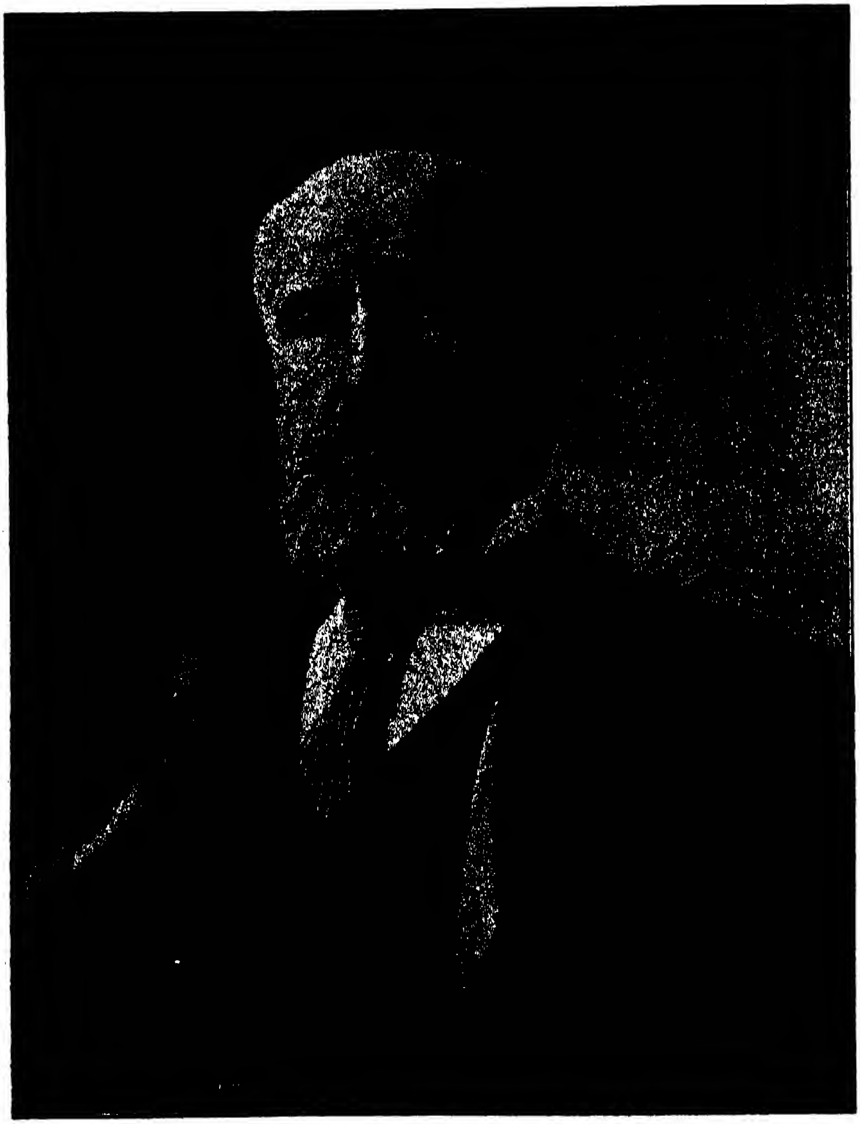
A HISTORY of psychology in America prior to the last fifty years would be as short as a book on snakes in Ireland since the time of St. Patrick. In so far as psychologists are concerned, America was then like Heaven, for there was not a damned soul there. Jonathan Edwards, the theologian, and Benjamin Franklin, the practical man, were our most typical representatives. In our colleges mental and moral philosophy was indeed taught, mostly Scotch, the importation of which was not prohibited in those days. Noah Porter, president of Yale University from 1871 to 1886, gave us the most elaborate text-book; James McCosh, president at Princeton from 1866 to 1888, performed the greatest service by sheltering physiological psychology and organic evolution under the cloak of Presbyterian orthodoxy.

There was no science of psychology in America fifty years ago; it may be that there was no organized science of psychology in the world prior to 1879. In that year Wilhelm Wundt established at Leipzig the first laboratory, Th. Ribot published his "La Psychologie allemande contemporaine," Francis Galton his "Psychometric Experiments," William James the first chapter of a work on psychology. In so far as psychology dates from 1879, this congress celebrates the jubilee of our science. The first congress of psychology met in Paris in 1889; the present congress marks the fortieth anniversary of our international cooperation.

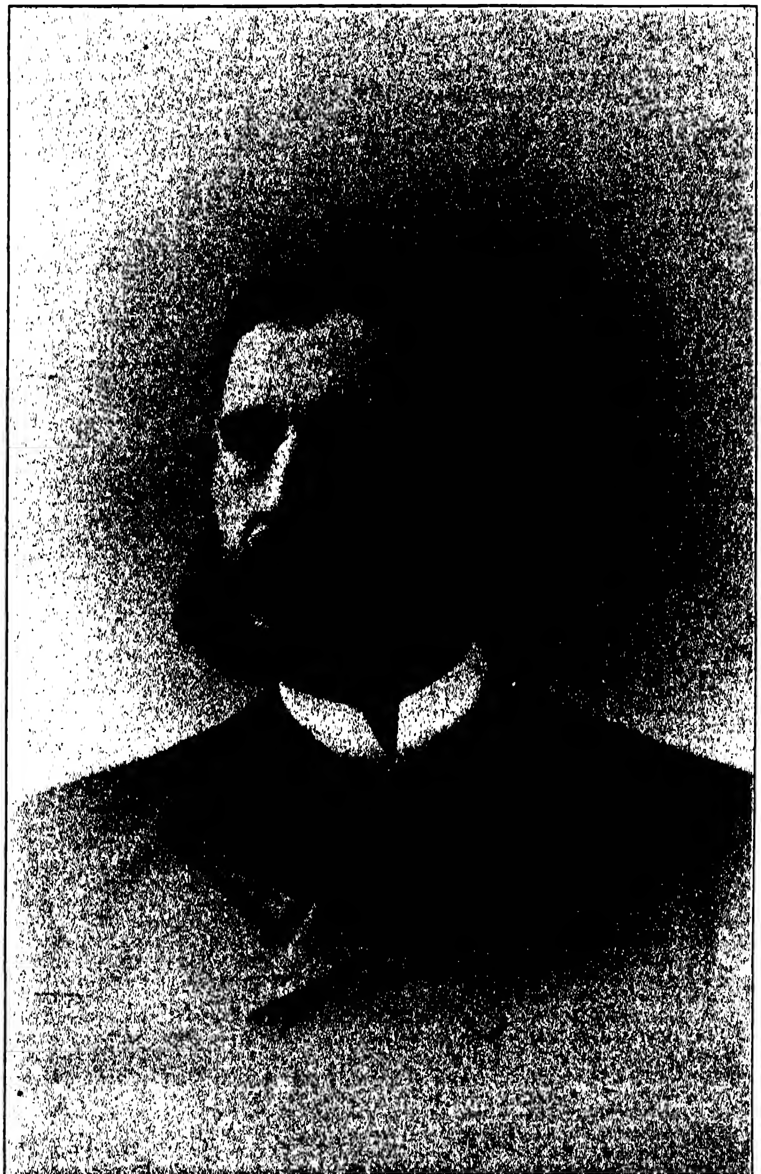
The pedigree of psychology, as of every science, can indeed be traced to Aristotle and the efflorescence of the Greek period, further back to the civilizations of Egypt and Asia Minor, dimly through the twilight and darkness hiding primitive men. If the making of fires and the use of tools, the cultivation of plants and the domestication of animals, were the beginnings of the physical and biological sciences, then psychology goes back to primitive speech, habits and customs. Perhaps the origins of psychology may be found in more remote pre-human, pre-mammalian and pre-vertebrate animals than those of any other science. The modern dog doubtless finds more differences between two individuals of its species than between a tree and a lamp-post that smell alike. Our early ancestors were mainly concerned with themselves, with their mates and their offspring, with the behavior of their fellows, of their prey and of their enemies. Satisfaction of desires, escape from danger and pain, efforts to foresee and to control the conduct of others, were the earliest and are the most fundamental of interests.

When such is so clearly the case, it may at first sight seem surprising that the sciences, both curious and useful, of matter and energy should have had an earlier origin and a more systematic development than the biological sciences, while psychology is only now taking its place among the descriptive sciences and has witnessed but its first beginnings as an applied science. The explanation is partly in the difference in stability and complexity of the objects of the different sciences. Matter is plastic to experiment and measurement; human behavior eludes experimental and quantitative methods. The motions of the solar system since its beginning are less

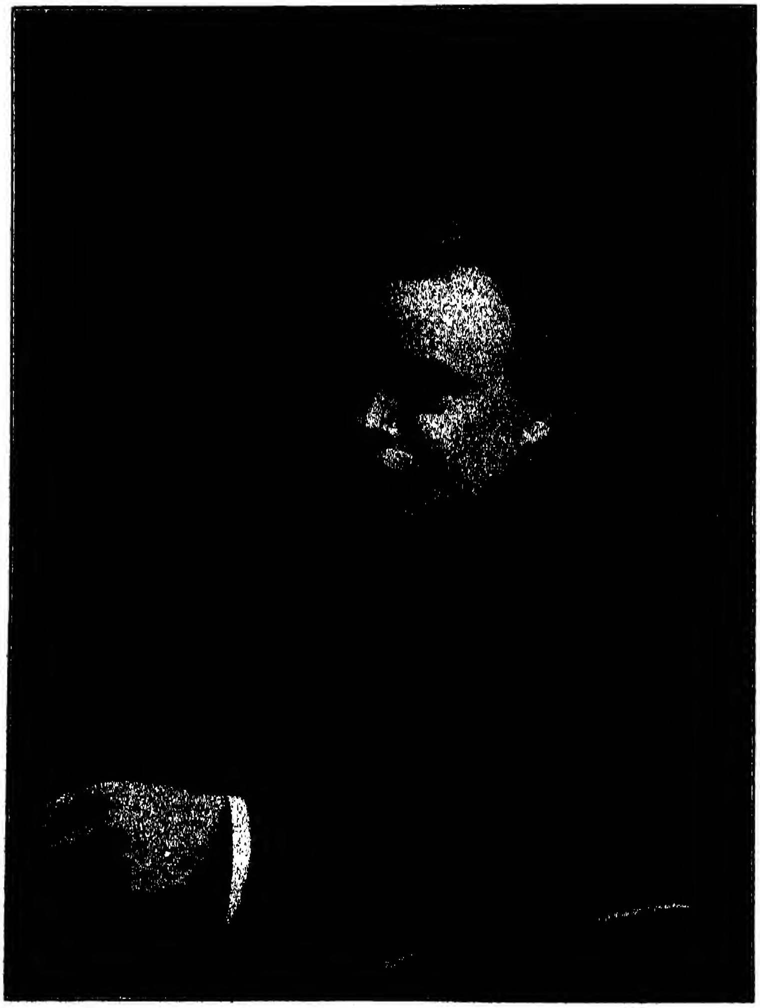
[1] From the Address of the President of the Ninth International Congress of Psychology, given at Yale University, New Haven, September 2, 1929.



G. Stanley Hall



George Trumbull Ladd



Josiah Royce.

complicated than the play of a child for a day. It is also the case that in the architectonics of science the mathematical and physical sciences are fundamental. Morphology and physiology are based on physics and chemistry; psychology on all these sciences. The foundations must be laid before we can build the upper stories, in which we may prefer to live and from which there may be the wider outlook.

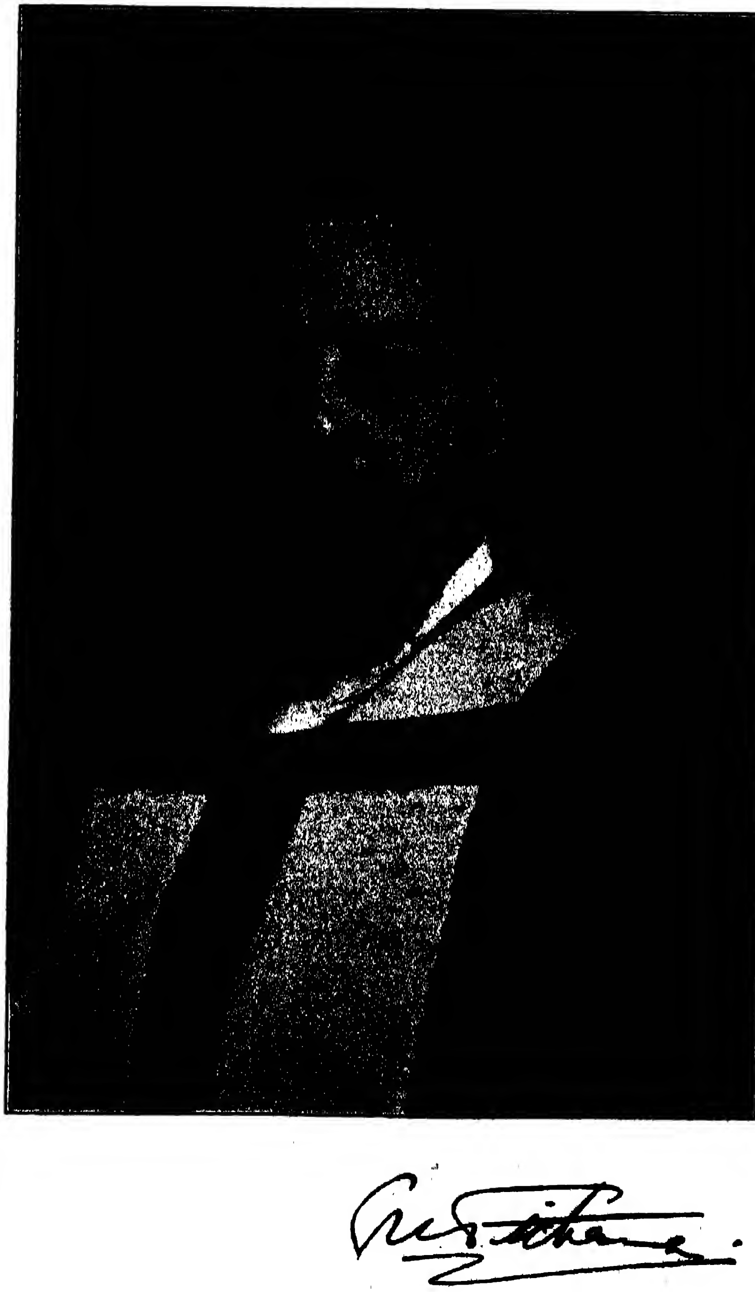
A less obvious reason for the late development of psychology is the circumstance that it is easier to satisfy needs and to control behavior by altering the environment than by altering individuals. The savage could learn to shoot an arrow from a bow or to move a stone with a lever more readily than he could strengthen his own right arm. He could obtain food better by planting corn than by developing his skill as a hunter. And so it is to-day. By increasing economic production we can do more for the welfare of people than by teaching them to be virtuous and wise. In America we have constructed a great civilization, not by trying to be civilized but by applying invention and organization to the exploitation of natural resources.

Psychology had to await the development of the exact and the natural sciences, whose objects are more open to measurement, whose contents are more basic, and whose applications are more useful. And it should be remembered that all the sciences, as we now know them, are comparatively new. The doctrine of the conservation of energy is only about as old as Professor Stumpf, the theory of evolution by natural selection about as old as Professor Jastrow. Modern physics and modern genetics are no older than the younger members of this congress. When sciences of earlier origin have made such notable advances during the lifetime of those now living, we may look forward with hopefulness to a corresponding development of psychology within the lifetime of our children.

Fifty years ago William James, born in 1842, was assistant professor of comparative anatomy and physiology at Harvard; Stanley Hall, four years his junior, was a student in Germany. As to other American psychologists there were—as Franklin said when asked if he had any children—"none to speak of." James was transferred to an assistant professorship of philosophy in 1880 and appointed to a professorship of psychology in 1889, resuming after eight years a chair of philosophy. He published in 1890 "The Principles of Psychology," a work of genius not often equaled in any science or in any language. Hall received the doctorate of philosophy from Harvard in 1878, one of the first awards of the degree, and was appointed lecturer there and at Williams College in 1880. In 1883 he became professor of psychology and pedagogy in the Johns Hopkins University, giving also the courses on philosophy. In that year he established the first American laboratory of psychology, unless we count as such the work by James at Harvard under physiological auspices, in which case it would antedate the Leipzig laboratory.

George Trumbull Ladd, eight days younger than William James, was called to a professorship of philosophy at Yale in 1881; he published in 1887 his "Outlines of Physiological Psychology," the first American book on the subject and, as revised by Professor Woodworth, one of the best. In that year there was established a lectureship and in 1888 a professorship of psychology at the University of Pennsylvania. This chair, held by me, was the first in any university here or abroad to be so named and in which the work of the professor was confined to psychology, the department being coordinate with philosophy and other university disciplines. In the laboratory were given the first experimental courses for students, the work at Leipzig and the Johns Hopkins having been limited to research.

Hugo Münsterberg.

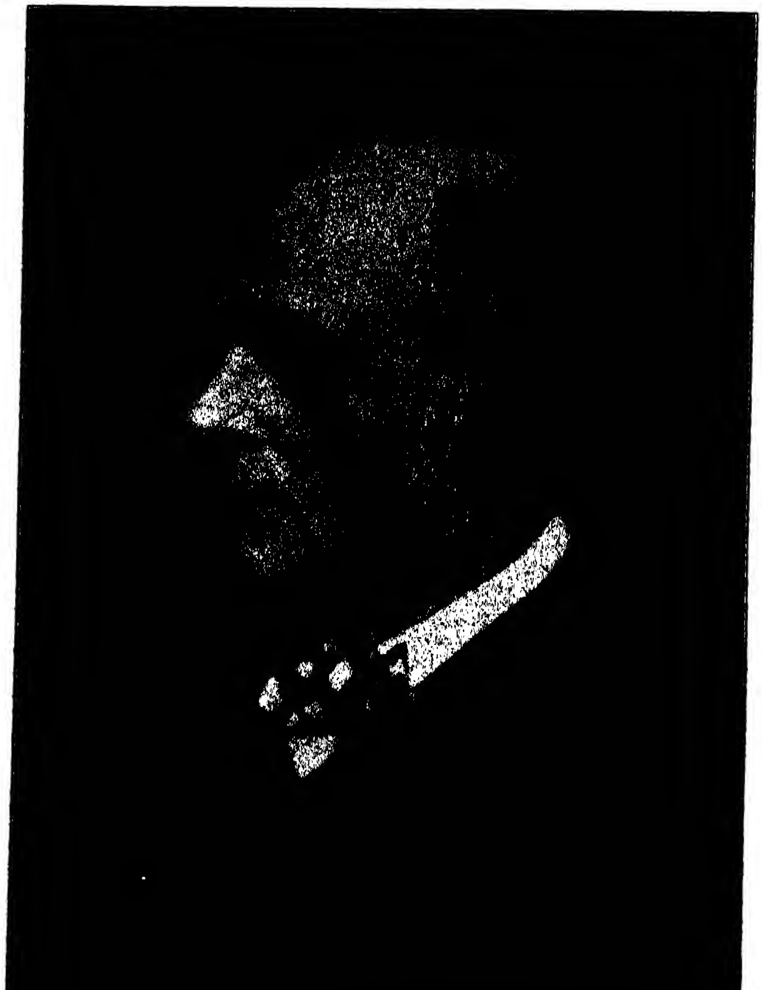


In rapid succession there were then established chairs of psychology and laboratories at Wisconsin under Professor Jastrow, at Indiana under Professor Bryan, at Nebraska under Professor Wolfe, at Brown under Professor Delabarre, at Wellesley under Professor Calkins, at Stanford under Professor Frank Angell, at Clark under Professor Sanford, at the Catholic University under Professor Pace, at Illinois under Professor Krohn, at Toronto and at Princeton under Professor Mark Baldwin. In 1891 a professorship and a laboratory were initiated at Columbia, a year later at Yale, Harvard and Cornell, Professor Münsterberg having been called from Germany to Harvard and Professor Titchener from England to Cornell. In this group should be included, for his contributions to psychology and education, John Dewey, professor of philosophy at Michigan, Minnesota, Chicago and Columbia. Josiah Royce, born in California in 1855, appointed assistant professor of philosophy at Harvard in 1882, a psychologist of distinction, alone bridges the gap between James, Hall and Ladd, our pioneers, and the second generation of American psychologists here in part enumerated.

The academic advance of psychology in America in the course of the four-year period from 1888 to 1892 is notable. There were no foundations as in Germany, England, France and Italy, in which countries a scientific psychology had for a hundred years or more been emerging from philosophy, and in which physics, physiology, zoology, neurology, psychiatry and other sciences had for an equal period been assembling subject-matter and methods that could be taken over by psychology. From our Declaration of Independence in 1776 until the founding of the Johns Hopkins University, exactly one hundred years, but little scientific research was accomplished in the United States and that little remote from psychology. There were Franklin, Rumford, Bache and Henry in physics, the Sillimans in chemistry, Gould and Chauvenet in astronomy, Peirce in mathematics, Torrey, Gray and Engelmann in botany, Agassiz, coming from overseas, Baird and Leidy in zoology, Dana, Hall, Lesley, Le Conte, Hilgard and others in geology, a practical science. But few of them have an international standing; there was none who helped to make straight the way for psychology.

The main condition favorable to the remarkable academic advance of psychology from 1883 to 1900 was the growth of our universities. Previously mental and moral philosophy had in most cases been taught by the president of the institution, qualified for both offices by being a clergyman, and when this situation changed it was natural to continue the teaching of psychology by special students of the subject. The enlargement of the universities and the adoption of the elective system permitted the introduction of a new science. Our people had curiosity, acquisitiveness and energy, with ever-increasing wealth. We were able to take over what we wanted from abroad; we were not bound by precedents and traditions. Even after years in our environment Professor Münsterberg claimed that "the presuppositions with which a science starts decide for all time the possibilities of its outer extension," and Professor Titchener said that he did not object to work on the measurement of individual differences in behavior so long as it was not called psychology. The psychologist has some reason to thank God when he is born a happy and irresponsible American child.

In comparison with literature and art, science is international. The velocity of light is the same whether measured by Fizeau in France or by Michelson in the United States. The electrons discovered by Thomson and measured by



Francis Galton

Millikan have the same hypothetical properties in Cambridge and in Chicago. The equations written by Einstein in Berlin are equally correct and equally relevant or irrelevant to the real world in Germany and in Japan. None the less the lines of advance followed by science are directed by the national life. It is not an accident that laboratory research in psychology is of German origin, that pathological psychology has been cultivated in France, that psychoanalysis has spread from Vienna, that Darwin and Galton were English, that objective psychology and the measurement of individual differences have had their chief development in the United States. Germany may keep its *Gestalt*, France its hysterics, Austria its *libido*, England its "g"; we shall continue to bear the burden of our meta-behaviorism.

America is part of the continuation of the cultural history of Europe. In psychology we owe to it everything up to the past fifty years, during which period there has been cooperation on terms that have now become equal. The two Europeans to whom our debt is the greatest are Wilhelm Wundt and Francis Galton. I had the privilege of working with both of them, as also with Herman Lotze and James Ward. Many Americans frequented the Leipzig laboratory, but perhaps only Titchener, who retained his British citizenship and outlook, continued its traditions. Stanley Hall and I were the first of Wundt's American students, but Hall worked in Ludwig's laboratory and I continued in my own rooms the work begun in America, in part because Wundt would not allow the testing in his laboratory of individuals who could not profit by introspection. Galton—the greatest man whom I have known—more nearly laid down the lines for the objective measurement of individual differences. But in his statistical methods of studying individuals he had been preceded by Quetelet and in America by Gould; in his study of imagery by Fechner, this work having been based on fallacious introspection. Wundt and Galton are the foreign psychologists whom we most honor, but it may be that if neither of them had lived psychology in America would be much what it is.

When Jefferson wrote in the Declaration of Independence that all men are created equal, he was referring to the unalienable rights to life, liberty and the pursuit of happiness. Where individual differences in rank and wealth are fixed by custom and law, they are taken as a matter of course. In a political and social democracy, such as has partly obtained in England and to a somewhat greater extent in the United States, attention is directed to the varying qualities of individuals. The wars of England are said to have been won on the playgrounds of its public schools. Competitive fellowships and scholarships, the mathematical tripos, arose in the English universities. The American college student wants to make his fraternity and the football team, sometimes also Phi Beta Kappa or Sigma Xi. Every boy may hope to become a Coolidge and get two dollars a word for his autobiography, or a Carnegie and try to make all university professors his pensioners. He learns that the race is to the swift and the battle to the strong. Those engaged at first in a conflict with nature, wild animals and savages, later in subduing the wilderness, now in the construction of a vast and complicated industrial civilization, are more likely to be interested in their own performance and in the conduct of others than to indulge in the refinements and the vagaries of introspection. It may be that there is American science and American psychology.

Of 84 Nobel prizes in science only five have been awarded in the United States, two of the recipients having been born abroad. No more were deserved.

We have not excelled in broad generalizations based on abstract considerations; but we have done more than our share in invention and in the applications of science. It is scarcely necessary to name a few from the long list of advances on which modern life is based which have had their origin or chief development here. Omitting the steamboat, the railway and other applications of steam, these include the cotton gin, the reaper and other agricultural machinery; the sewing machine, the refrigerator, the vacuum cleaner and other household machinery; the typewriter, the manifolder and other office machinery; all sorts of factory, foundry and mining machinery and methods; steel and cement construction; central heating; electric light and electric power; the telegraph, the telephone and the radio; the phonograph and the motion picture; the automobile and the airplane. It may be that trial and success methods, so important in learning by the individual, are equally fundamental in learning by the race and in the advancement of science. Who devised the Greek temple and the Gothic cathedral? The most magnificent architecture since these is here arising before our own eyes, but no one knows who is responsible for it. The proximate cause of the New York sky-scraper is an ordinance of a board of aldermen, prescribing that, in order to conserve light, high buildings must be recessed from the street.

The situation is the same in psychology. The advances in America are due to the work of uncounted individuals, many of them not known as psychologists. It appears that I was the first to publish psychological measurements of individual differences without regard to introspection and with special reference to their useful applications, but that is because I had the misfortune to be born a long time ago. So Columbia University and its Teachers College may have done the most—more than 150 members and associates of the American Psychological Association hold its doctorate —to advance objective, individual and group psychology, especially in its applications to education. In a sense this is due to Professor Thorndike, Professor Woodworth and other leaders who have worked with me, but it is in the main a manifestation of economic and other factors of our national life. Psychologists have been academic teachers and have naturally taken up problems concerned with children and schools. Other aspects of objective psychology to which these lead have been measurements of animal behavior. We are apparently somewhat behind Germany in the applications of psychology to industry, but we have a large development of industrial management and personnel work—the Taylor system is American—which will ultimately be taken over by official psychology. Even our swarms of cranks in the air above and our shoals of charlatans in the water beneath may be found to have contributed their bit, when natural selection and survival of the fit are given ample time.

It is not intended to discuss here the relative extent to which progress is due on the one side to great leaders, on the other to the activities of large numbers of individuals reacting to economic and other conditions. It seems, however, that the chief contribution of America to psychology has not been large philosophical generalizations, but the gradual accumulation from all sides of facts and methods that will ultimately create a science, both descriptive and applied, of human nature and human behavior. Each of us, as the English poet Clough says,

> must slave, a meager coral-worm,
> To build beneath the tide with excrement
> What one day will be island, or be reef,
> And will feed men, or wreck them.

THE TRIANGULATION SYSTEM OF THE UNITED STATES

By Dr. WILLIAM BOWIE

CHIEF, DIVISION OF GEODESY, U. S. COAST AND GEODETIC SURVEY

TRIANGULATION, as is well known, is a method used by surveyors and map makers to determine distances between points and to determine the geographic positions of these points over wide expanses of the earth's surface. In its simplest form, triangulation consists in the measurements with bars or metal tapes of the distance between two intervisible points. This measurement of the base is followed by the measurement of the horizontal angles of a triangle whose vertices are the two base ends and another point which may be observed from them. With one side of the triangle known and the three angles observed, one can by use of simple trigonometrical formulas derive the lengths of the other sides of the triangle.

In practice, chains of triangles are extended along a coast or in the interior of a country. The computed lengths of the sides of the triangles are, in turn, used as bases for other triangles. At intervals of fifty or one hundred miles or some other distance, depending on the character of the terrain, a new base will be measured in order to strengthen and to control the lengths computed through the chain of triangles from the first base.

Since the earth's surface is curved, consideration must be given to the dimensions of the earth in computing the latitudes and longitudes of the triangulation points. The latitudes are referred to the equator, while the longitudes are referred to the initial meridian passing through the observatory at Greenwich, England.

The first triangulation in the United States was executed in 1816 by Ferdinand Hassler, the first superintendent of the Coast Survey. The observations for this triangulation were made in the vicinity of New York. From that time till the present, triangulation has been executed by the Coast Survey (the name was changed to Coast and Geodetic Survey in 1878) until now there are 35,000 miles of arcs of triangulation extending along portions of the coasts, along the boundary between the United States and Canada and that between the United States and Mexico, and through the interior of the country.

There are several orders of triangulation used in surveying, mapping and other engineering operations, classified according to the accuracy with which angular measurements are made. The simplest measure of accuracy in triangulation is the closing error of a triangle, which is the difference between the sum of the three observed angles and 180 degrees plus the spherical excess of the triangle. Since each of the triangles, especially in first-order triangulation, covers a considerable area of the earth's surface and this surface is curved, the sum of the angles is necessarily greater than 180°.

In first-order triangulation the average closing error of a triangle is about 1″, with a maximum closing error seldom exceeding 3″. In second-order triangulation the average triangle closing error is between 1.5″ and 3″, while third-order triangulation has closing errors which average somewhat more than 5″.

The fundamental triangulation system of this country is composed of first- and second-order triangulation. It is planned to have the first-order arcs spaced at distances of approximately one hundred miles, while the intermediate areas will be crossed by arcs of second-order trian-

gulation. When the fundamental triangulation net of the country has been completed there will be few places more than about twenty-five miles from an arc of either first- or second-order work.

There are now in the United States 26,600 miles of arcs of first-order triangulation and something less than 1,000 miles of second-order work. There will be needed, to complete the net, about 48,400 miles of arcs of first- and second-order triangulation.

In the United States a plan somewhat different from that employed in many of the European countries is followed. There the total area is covered by a connected system of triangles of first order, with supplemental points classed as first and second order according to the accuracy of the observations with which they were established. We have, however, a different problem. Our area is vast, approximately 3,000,000 square miles, as compared, for instance, with the area of France which is 210,000 square miles or that of Holland which is 12,600 square miles. Our problem of covering the entire country with control triangulation is so great that it is believed to be satisfactory, both from the practical and the scientific standpoint, to have the arcs of first-order triangulation spaced at intervals of about one hundred miles, in the form of a network in order that the adjusted values may have the requisite strength. Then, as mentioned above, the intermediate areas will be crossed with arcs of second order, and the next intermediate spaces will be covered with third-order triangulation. The latter is designed to meet the immediate needs of the topographic engineers and the engineers locating the boundaries of private property, counties and states.

I wish to emphasize the great importance of triangulation in the many industrial and commercial activities of our people. We are more inclined to look on triangulation as a scientific problem and to think that the greatest benefits arise from its use in attacking certain research problems.

While the development of instruments and methods in the execution of triangulation and the computation and adjustment of the results have been real scientific problems, yet the results of the work have been of tremendous value in the practical affairs of man. The topographic map of the country, which is essential to all engineering work involving the extension of highway systems, flood control of rivers and their utilization for transportation, the development of hydroelectric power, the development of the network of telegraph and telephone lines for communication and power lines to transmit electricity, must be based on accurate geographic positions which can be determined by triangulation only. In addition, the triangulation net of the country will make it possible for the owner of each piece of property, whether city lot or farm, to have the corners of his property expressed in terms of latitudes and longitudes, and thus his boundaries are perpetuated regardless of whether or not the boundary monuments have been destroyed. There is only one place on the earth's surface which has a given latitude and longitude, and when that is known the point can be recovered at any time even if the station mark is destroyed. The saving to property owners will be great and litigation over political boundaries can be reduced to a minimum by the use of boundary surveys based on accurate triangulation.

There are many scientific uses for triangulation which alone would justify the expense involved in its execution. As is well known, one of the uses of triangulation is the determination of the figure of the earth. It is only by such work that one can determine over broken terrain the linear distances between widely separated points. When these distances are known and the astronomical latitudes and longitudes of the terminal points have been determined we have the data

which are essential in the computation of the length of an arc over the earth's surface.

Many years ago it was deemed that only meridional arcs of triangulation were needed in the determination of the figure of the earth, but in late years it has been learned that a stronger value can be obtained by the use of the area method. The astronomical observations are affected by the configuration of that portion of the earth's surface over which the measurements are made. It is well known that mountain masses and high plateaus will deflect the plumb line or the direction of gravity to which astronomical observations are referred. Along our coasts the plumb line is deflected inland. By astronomical observations, therefore, we would have too many degrees, minutes and seconds of arc along an east and west line running across the United States. However, if we have many arcs of triangulation connected into a net with numerous astronomical stations at which the latitude and longitude have been determined by observations on the stars we are enabled to minimize the effect of the deflections of the vertical caused by topographic features.

The late Professor John F. Hayford, when he was in charge of the geodetic work of the Coast and Geodetic Survey, devised a method to test isostasy by the use of triangulation and astronomical data. He found that the topographic features did not deflect the direction of the plumb line as much as their masses would lead one to suspect. Isostasy, however, postulates that the density under elevated regions is less than normal, while under depressed regions of the earth's surface the density is greater than normal. This idea was given a quantitative test by Hayford, and it was found that the difference between the astronomical longitude and latitude of a station and geodetic latitude and longitude, obtained by triangulation methods for the same station, would be largely accounted for when isostasy was applied. We thus see that triangulation furnishes data which can be used in exploring the regions that lie below the earth's surface far beyond the reach of the deepest mines or wells. This test of isostasy made with triangulation and astronomical data has been supplemented by investigations involving values of gravity taken at hundreds of places over this and other countries. The isostatic investigations have shown that the thickness of the earth's crust is of the order of magnitude of sixty miles. The crustal material has residual rigidity, while the material below it acts as if it were plastic to long-continued stresses. The establishment of isostasy as a scientific principle will have a profound influence on the solution of many geophysical and geological problems. Thus we can see that the geophysicists and geologists have been benefited by triangulation.

The lengths in triangulation depend on measured base lines. A base line is merely the side of one of the triangles. The measurements of base lines are now made in this country with invar tapes or ribbons fifty meters in length. These tapes are standardized at the Bureau of Standards with a probable error in the derived length of not more than one part in a million. The bases are measured at least twice and with different tapes. The probable error of the actual field measurements is seldom greater than one part in two million. These probable errors lead us to believe that there are few or no base lines used in first-order triangulation in this country which have greater actual errors than one part in 300,000.

The triangulation is strengthened by the use of what are termed Laplace azimuths. A Laplace azimuth is derived from azimuth observations on Polaris, by correcting for the tilting of the meridional plane at the point of observation. The amount of this tilting is obtained from the difference of the longitudes at

the station as derived by astronomical and geodetic methods.

In the adjustment of about 13,000 miles of arcs of first-order triangulation in the western half of the United States a few years ago fifty base lines and seventy-four Laplace azimuths were used. There are sixteen closed loops in this net. The adjustment was made by a method devised by the author, which was perfected and worked out in its details by Dr. O. S. Adams, a mathematician of the Coast and Geodetic Survey.[1]

The results of this adjustment, the only one of its size ever undertaken in the world, were surprising even to the officials of the Coast and Geodetic Survey who had been engaged on geodetic work for a score or more of years. The average length of the perimeter of a circuit was 1,200 miles. The average closing error of the sixteen loops of the net in the western half of the country was one part in 450,000 of the length of the perimeter. The average correction to a section of the triangulation adjoining junction points was one part in 320,000. There were only two loop closures which were greater than one part in 200,000, and there were only four of the forty-two sections joining junction points which had corrections greater than one part in 150,000. The outside perimeter of the whole net had a length of 5,284 miles, while the closing error of this perimeter was only 33.1 feet, or one part in 842,000.

It would seem from the results of this net adjustment that distances can be measured across country with an error that is seldom greater than one part in 100,000. This statement applies to distances from a few miles up to perhaps 150 miles. With greater distances the accuracy becomes increasingly greater. This is undoubtedly due to the fact that the errors in the base and angle measurements and in the Laplace azimuths are accidental in character and their effects tend to be eliminated over great distances.

The scientific world will be glad to learn of the great accuracy with which distances can be measured by triangulation, for a very important use for geodetic work is in determining the stability of the earth's surface in both the horizontal and vertical directions. Triangulation has already been used for this purpose in this and other countries. Prior to the 1906 earthquake in California the Coast and Geodetic Survey had extended an arc of triangulation from the vicinity of San Francisco Bay southward to the Mexican border. This work was first order in accuracy, and the results were used as a base from which to make tests of the extent to which earth movements had occurred in the interval elapsing between the date of completion of the early triangulation and the time of the recent triangulation. The old triangulation stations were reoccupied and the angles reobserved during the years 1923–26. A comparison has been made of the old and the new triangulations having identical points of observations, and much has been learned as to the extent to which horizontal movements occurred in the regions covered by the investigations. There have been some decided movements with the general direction of movement to the southeastward at stations east of the San Andreas fault, while on the west side the direction of movement has been to the northwestward. It is rather remarkable that no movements were detected south of San Luis Obispo or east of triangulation stations Monticello and Vaca.[2]

The results of this comparison of the old and new triangulations in Cali-

[1] See Oscar S. Adams, "The Bowie Method of Triangulation Adjustment, as Applied to the First-order Net in the Western Part of the United States," Coast and Geodetic Survey Special Publication No. 159 (in press).

[2] See William Bowie, "Comparison of Old and New Triangulation Stations in California," U. S. Coast and Geodetic Survey Special Publication No. 151.

fornia were so encouraging that the Coast and Geodetic Survey in cooperation with the members of the advisory committee on seismology of the Carnegie Institution effected plans for making very detailed tests of the earth movements, or at least they have planned to lay the basis for such work. As a result of conferences of committee members and officials of the survey an arc of triangulation ninety miles long, extending from Newport Beach to Lucerne Valley, has been executed. The work consists of a main chain of triangles with a system of supplemental triangles. The main arc is first order in accuracy, while the angles of the supplementary triangles were observed with second-order accuracy. Along certain fault lines the stations were placed very close together in order that in the future, should an earthquake occur, detailed information might be obtained as to how far from the fault movements took place and also the directions of those movements. There were ninety-four first- and second-order stations occupied in this arc. It will be noticed that the stations are very much more closely spaced than on the arc extending from San Francisco to the Mexican border where the tests have already been made.

Additional arcs of triangulation in California will be executed across fault zones as a basis for studies of horizontal movements of the earth. The observation on these arcs will be repeated should an earthquake occur near one of them, or perhaps at intervals of five to ten years the angles will be reobserved even though no earthquake may have occurred. It is held by many that earth movements probably take place before the earthquake occurs. It will be interesting to learn whether the California triangulation will show this to be true.

The most exact piece of triangulation ever executed in the world as far as the author is aware was that for the determination of the distance between Mount Wilson and San Antonio Peak, California. The value of this distance was required by Professor A. A. Michelson in his determination of the velocity of light. Every known precaution was taken in making the measurements of the base line and the angles involved in the triangulation extending from the measured base to the line joining the two peaks. The probable error of the length of the base from field measurements alone was one part in 11,600,000, while the probable error of the computed distance between the two mountain peaks was one part in 6,800,000. Of course these probable errors must be combined with the probable errors of the standardization of the base tapes at the Bureau of Standards. The probable error of the standardization of each tape was about one part in a million and there were eight tapes used in the base measurements. The tapes were standardized both before and after the field measurements. It is not possible to know the exact error in the line joining the peaks, but it is believed that it is not greater than one part in one million. The distance furnished Professor Michelson by the director of the Coast and Geodetic Survey was 35,373.21 meters.

It seems evident from the above that the results of triangulation have important practicable and scientific uses and that the completion of the net within the next ten years or so will greatly aid the people of this country.

The geodesist has not been able alone to make the great improvements in triangulation methods and instruments during the past hundred years. He has been assisted by the mechanical engineer, the physicist and the astronomer. The combined efforts of all three have brought triangulation methods and instruments to a very high degree of perfection, but in spite of this we may look forward to other improvements in the years to come.

SIGNIFICANT DEVELOPMENTS REGARDING SOIL CORROSION

By HENRY W. HOUGH

ASSOCIATE EDITOR, *The Scientific American*

CORROSION, particularly of the ferrous metals, presents a serious industrial and economic problem. Iron is found in nature in combination with various other elements in a condition of stable equilibrium. To adapt it to our needs we extract and refine the ore, imparting to it certain qualities of usefulness. But in the process certain characteristics are developed that result in a natural tendency on the part of the metal to return to a more stable condition by the familiar process known as corrosion. For years industrial research workers and other metallurgists have been seeking practical means of overcoming this objectionable weakness of the ferrous metals, but the available "remedies" are quite impractical.

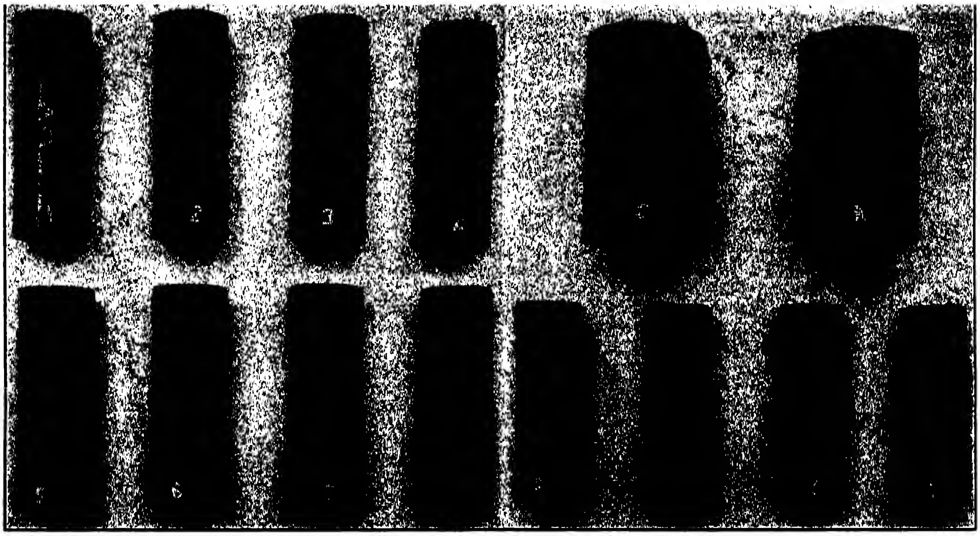
The electrochemical theory of corrosion has been accepted by most metallurgical authorities. It presents a plausible explanation of the oxidation of the ferrous metals, although certain individuals have pointed out that the theory may be said to fall short of accounting for the corrosion of copper and other metals that are below hydrogen in the electromotive series.

According to this theory, iron and steel corrode as a result of the following reaction, when water comes in contact with the surface of the metal: the water forms as hydrogen ions and hydroxide ions; the hydrogen ions are positive and dissolve an equivalent amount of iron. The dissolved iron ions then combine with the oxygen in the hydroxide ions, which are negative. The product is neutral iron oxide, and an excess of hydrogen ions which are forced out of solution and emerge as hydrogen gas.

If the corrosive action is not violent, the tiny globules of hydrogen lie along the surface of the metal in an almost invisible film, tending to retard further oxidation of the metal. If the reaction is sufficiently violent, as when the electrolyte is an acid solution, the hydrogen is evolved so rapidly that it forms bubbles which float to the surface of the solution.

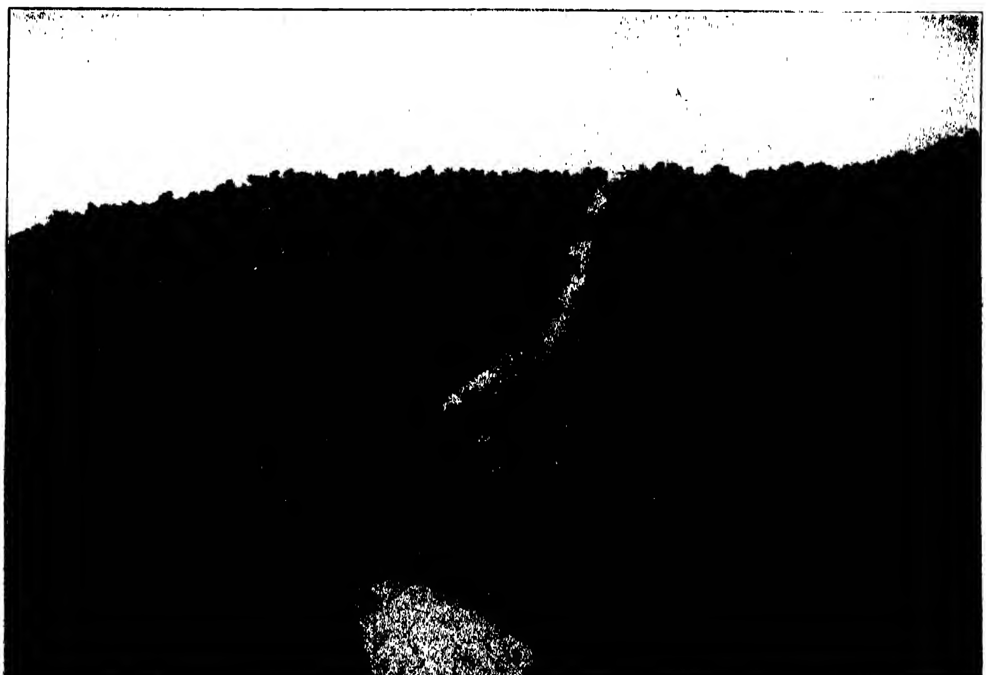
One of the simplest accelerated corrosion tests is to invert a test-tube over a submerged piece of metal in a vessel filled with water or an acid solution. As the hydrogen is evolved, it accumulates in the closed end of the tube and can be measured easily. It is presumed that the amount of hydrogen evolved during the reaction is directly proportionate to the amount of metal consumed, and that the rate at which the hydrogen is evolved is the equivalent of the rate of corrosion.

Within the past few years the study of soil corrosion has advanced materially as a result of several well-planned developments. Of these, the most significant are: (1) The U. S. Bureau of Standards studies regarding the effect of corrosion on various metals buried in various locations throughout the country, in soils classified according to physical characteristics; (2) the research of Dr. H. D. Holler, supplementing the work of the Bureau of Standards, regarding the effect of certain factors in soils which govern their corrosiveness; (3) the development of a method by which representative soil samples are analyzed and given corrosion ratings according to inherent chemical and physical characteristics, and the develop-



EFFECT OF CORROSION

ON SAMPLES OF THE SAME METAL BURIED IN DIFFERENT SOILS AND DIFFERENT METALS BURIED IN ONE LOCATION, SHOWING THAT SOIL CHARACTERISTICS CONTROL THE NATURE AND EXTENT OF CORROSION.



TYPICAL TOPOGRAPHICAL SITUATION

ALONG THE RIGHT-OF-WAY OF A LONG NATURAL-GAS PIPELINE, SHOWING SURFACE CHARACTERISTICS WHICH MUST BE TAKEN INTO CONSIDERATION WHEN PREDETERMINING THE INTENSITY OF CORROSION.

CORROSION MUST BE ANTICIPATED

AND GUARDED AGAINST TO PREVENT UNTIMELY DESTRUCTION OF IMPORTANT PIPELINES, SUCH AS THIS ONE WHICH NOW SUPPLIES MEMPHIS, TENNESSEE, WITH GAS FROM LOUISIANA.

THESE NATURAL-GAS PIPELINES

AT A MISSISSIPPI RIVER CROSSING ARE BEING COATED WITH A THICK LAYER OF ENAMEL, WHICH WILL PROTECT THE METAL FROM CORROSION.

ment of an adaptable system for balancing these ratings with relevant surface characteristics in any given location, for the purpose of determining the relative intensity of corrosion to be expected in various areas.

The investigation of the Bureau of Standards was begun in 1922, with the Bureau of Soils and a number of pipe and coating manufacturers cooperating. Samples of various metals, both protected and unprotected, were buried in test pits located in about forty cities representing different sections of the country. The samples removed after two- and four-year periods were described in the bureau's Technologic Paper No. 368, and more recent data now available will give complete information regarding the manner in which the soils were classified, the materials used in the tests and conclusions drawn after making a study of the specimens removed.

A number of significant observations were made by Mr. K. H. Logan and his associate in the paper mentioned above. A few of these will be mentioned here.

> Both the 1924 and 1926 specimens indicate that the type of corrosion is in some way associated with the locality in which the specimens are buried. It has been assumed that the effects found are due to some characteristics of the soil of the locality. Serious corrosion has been observed in several localities . . . attention should also be called to the fact that in a majority of soils the rate of corrosion is low, and in some it is practically negligible.

Referring to the comparative merits of the various metals tested, the authors of the paper said:

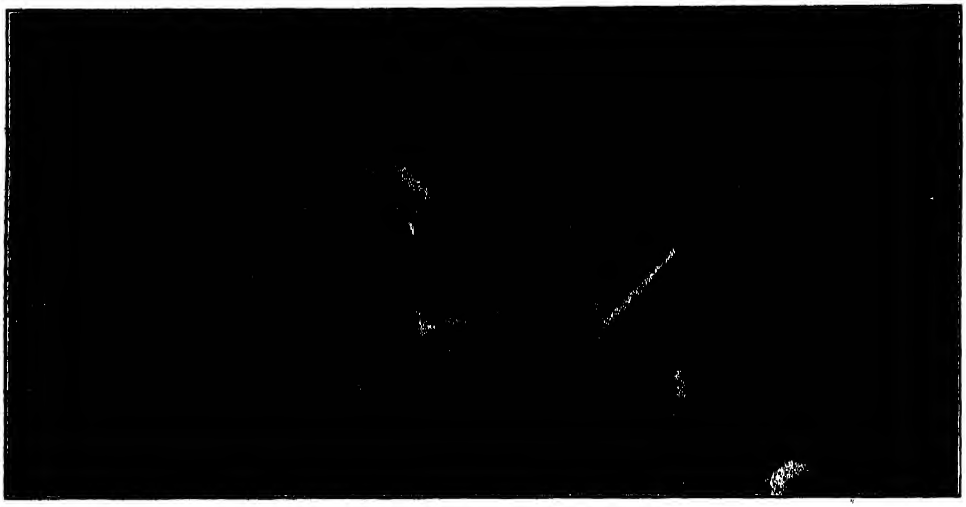
> While no one material that is suitable for general use for pipelines now appears to be superior to all others in all soils, there is an indication that a saving can be effected by the proper selection of a pipe material with respect to soil conditions.

It is understood by all parties interested that the relative length of life of such materials as steel and wrought iron can not be estimated accurately until the specimens have been exposed to corrosive action for several more years.

TAKING SOIL SAMPLES

ON THE RIGHT-OF-WAY FOR A PROPOSED PIPELINE, PREPARATORY TO DETERMINING THE POTENTIAL CORROSIVENESS AT VARIOUS POINTS.

Although most of the paints and other protective coatings applied to the samples were too thin to give reliable com-



THE EXTRACTED DIRT IS ROLLED

AND QUARTERED DOWN AS IN MINE SAMPLING IN ORDER TO ASSURE A REPRESENTATIVE SAMPLE OF THE SOIL TO BE TESTED.

parisons of their value, it was determined that

> a coating satisfactory for one soil may not be satisfactory for another, and in order to use data on protective coatings tested in one locality for predicting results to be obtained in another locality, soil conditions must be studied.

While engaged in studies concerning these samples, Mr. Logan had noticed the presence of galvanic currents along a pipeline situated at a considerable distance from any known power source. In certain locations or in certain soils the currents flowed from the soil to the pipe, while in nearby locations the current was found to be flowing from the pipe to the soil. Although the importance of such currents with respect to corrosiveness is not well understood, it was believed that they might be interpreted as evidence of the electrochemical nature of soil corrosion.

Dr. H. D. Holler has substantiated the theory that the rate of corrosion is proportionate to the rate at which hydrogen is produced and removed from the surface of iron or steel. This is in accordance with the equations (Whitney):

$$Fe + 2H^+ = Fe^{++} + 2H,$$

or

$$Fe + 2H_2O = Fe(OH_2) + H_2.$$

In the studies conducted by the Bureau of Standards, the investigators were handicapped by insufficient data concerning the soils in which metal specimens have been buried. It was found that the classification of soils according to texture and other physical characteristics was misleading and of no value in appraising their potential corrosiveness. No data were obtained to show the amount of moisture in the various test pits. Water, of course, is the most important factor in corrosion; it provides the all-important hydrogen, dissolves soluble salts and other potentially active ingredients in the soil and regulates both the rate and duration of the corrosive action.

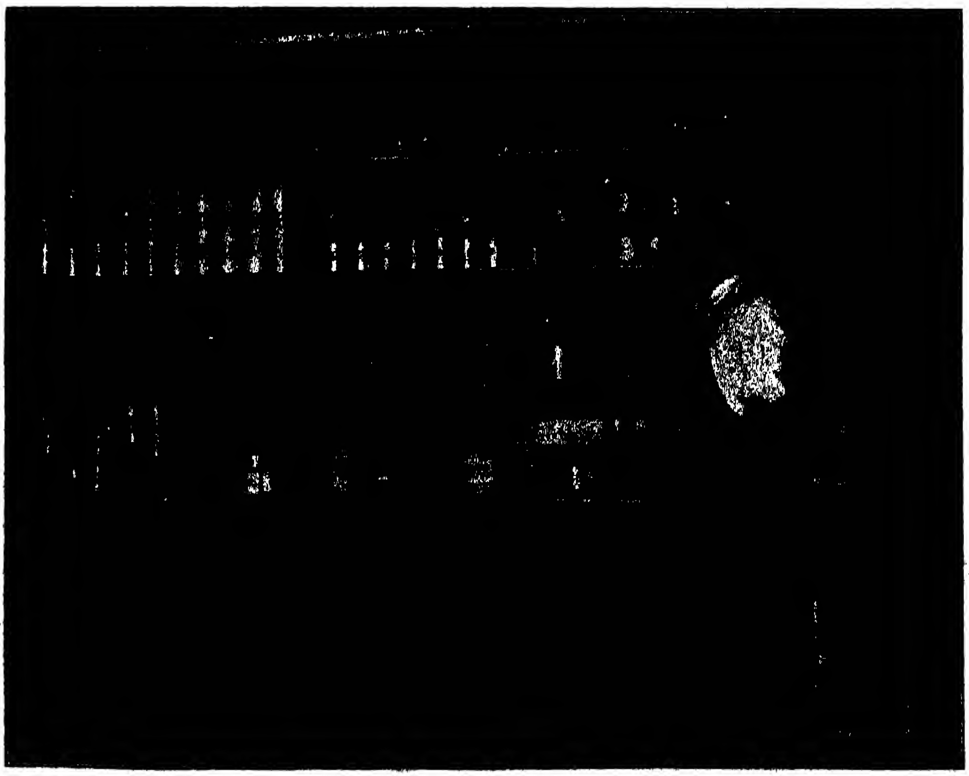
Appreciating the need for more adequate knowledge about the corrosive characteristics of soils, an engineer and a chemist collaborated in developing a practical method for determining the relative intensity of corrosiveness in any prescribed area. This method, orig-

inated and developed by Mr. P. J. Richards and Mr. William Thompson Smith, is known as a soil corrosion survey.

When making a corrosion survey of the right-of-way for a pipeline several hundred miles in length, the following procedure is used. Samples of the soil are taken, at intervals of not more than one mile and at the depth at which the pipe will rest when in service. A topographical survey is made, noting the amount of moisture, degree and direction of slope, vegetation and both present and probable use of the surface of the land. Rainfall records and local weather conditions are taken into consideration.

The samples are marked, shipped to the laboratory and classified according to location. The moisture content is determined by weighing, air-drying and reweighing a portion of the soil in each air-tight container. A solution is then made, by mixing a portion of each sample with distilled water, to determine by analyses the content of various water-soluble salts. Analyses of the soil as received are made also, because of the possibility that certain chemicals present may become soluble later, although insoluble in water in their present state.

The pH value, or active acidity, of each solution is determined by the La-Motte method. Since the active acidity of a solution is usually only a part of its total acidity, which is determined by titration, too much reliance can not be placed on the pH value alone. Never-



HUNDREDS OF SOIL SAMPLES

WHICH HAVE BEEN SUBJECTED TO A COMPREHENSIVE SERIES OF CHEMICAL, PHYSICAL AND ACCELERATED CORROSION TESTS TO DETERMINE THEIR RELATIVE CORROSIVENESS.

TESTING FOR ACTIVE ACIDITY, OR pH VALUE

SOLUTIONS MADE FROM REPRESENTATIVE SOIL SAMPLES; THE TOTAL ACIDITY IS DETERMINED BY TITRATION.

theless, the determination of the pH is highly important in appraising the potential corrosiveness in soils.

With this accumulation of analytical data and the facts obtained from the topographical survey the next step is to correlate the various factors at each location in order that each sample can be given a relative corrosion rating. It is one thing to "analyze" soils, and quite another to interpret the final results in terms of relative corrosiveness. The relative proportion of soluble salts, the amount of moisture, the drainage situation, the active acidity and total acidity and other accelerating or inhibiting factors are balanced and evaluated in what has been found to be their proper relation to each other and to all other known factors.

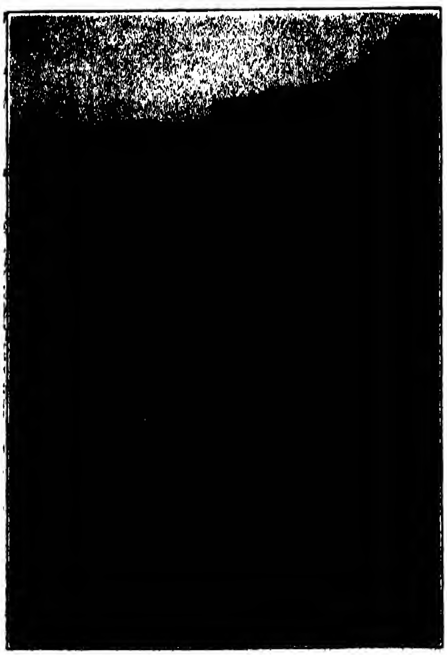
It may be well to quote Mr. Richards, who directs laboratory and field work in connection with the surveys, concerning this phase of the procedure.

> We have found that neither a chemical analysis of soils, nor a topographical survey, will give information of sufficient value to determine the probable corrosion to the pipe. Both must be completed and considered together and as a whole, before a reasonably accurate estimate can be made.

Surveys made in the west have substantiated the opinion of Dr. Holler that in arid regions (such as the eastern watershed of the Rocky Mountains, where large areas are arid or semiarid) soil corrosion is dependent on the soluble salt content of the soil. In Mississippi, Alabama and Georgia the corrosion surveys have shown that the total acidity is

usually the predominating factor. In general, the soils of the east are acid and those of the west are alkaline; in any locality, however, a high percentage of alkalis will tend to neutralize an acid soil, and *vice versa.* When possible, control samples of known corrosiveness are analyzed, to learn what factors have influenced corrosion in the locality, under field conditions.

With the cooperation of the Bureau of Standards, soil samples from about thirty-five of the test pits were analyzed at the Richards laboratory, in accordance with the method used on commercial surveys. The samples were dry when received at the laboratory, rather than in the customary air-tight containers, making it impossible to gauge the moisture content of the soils. However, the usual analyses were made, the results



THE GREAT VARIETY OF THE TOPOGRAPHICAL CONDITIONS

ENCOUNTERED BY ENGINEERS IN CONSTRUCTING LONG-DISTANCE OIL AND GAS PIPELINES; THE CORROSION SURVEY SOMETIMES REVEALS DANGEROUSLY CORROSIVE AREAS IN LOCATIONS THAT WOULD APPEAR TO BE QUITE SAFE FROM SEVERE CORROSION

were correlated and each sample was given a corrosion rating.

These ratings were then checked against the actual corrosion record of the soils, which had been measured and tabulated by the Bureau of Standards after the metal specimens had been removed from the pits. Despite the fact that no data had been available to show the amount of moisture in the soils, the analytical ratings checked the actual corrosion record to such a degree as to leave little doubt as to the reliability of the method.

When corrosion surveys are made in other places, the procedure is altered to meet any local situation. In the city of Pueblo, Colorado, corrosion is extremely severe in the north and east sections, but in the southern part there are practically no corrosion leaks in piping. The corsosive soil contains relatively large amounts of calcium and magnesium sulphates, and is principally clay, which accelerates corrosion because it holds moisture. In the other soil, there are very small proportions of sulphur, sulphates and chlorides, and instead of gypsum the soil is sandy and well drained. Here, as in other places, it has been possible to ascertain the governing corrosive factors and chart the different areas.

To summarize, the Bureau of Standards has contributed valuable data as to the effects of corrosion on various metals buried in different locations, showing that the inherent characteristics of the soil are the dominating factors influencing corrosion. Dr. Holler has confirmed the theory that the rate of corrosiveness is proportionate to the rate at which hydrogen is evolved and removed from the surface of the metal. In addition to these developments, there has been significant progress in working out a practical method for appraising and charting the relative intensity of soil corrosion in various locations by making a complete corrosion survey of all local factors.

While it is obviously impossible to mention all the important developments produced by recent soil corrosion research, these outstanding accomplishments will serve to show the significant trends and their effect in ameliorating the ever-present corrosion problem.

THE PROBLEM OF THE WILDERNESS

By ROBERT MARSHALL

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I

It is appalling to reflect how much useless energy has been expended in arguments which would have been inconceivable had the terminology been defined. In order to avoid such futile controversy I shall undertake at the start to delimit the meaning of the principal term with which this paper is concerned. According to Dr. Johnson a *wilderness* is "a tract of solitude and savageness," a definition more poetic than explicit. Modern lexicographers do better with "a tract of land, whether a forest or a wide barren plain, uncultivated and uninhabited by human beings."[1] This definition gives a rather good foundation, but it still leaves a penumbra of partially shaded connotation.

For the ensuing discussion I shall use the word *wilderness* to denote a region which contains no permanent inhabitants, possesses no possibility of conveyance by any mechanical means and is sufficiently spacious that a person in crossing it must have the experience of sleeping out. The dominant attributes of such an area are: first, that it requires any one who exists in it to depend exclusively on his own effort for survival; and second, that it preserves as nearly as possible the primitive environment. This means that all roads, power transportation and settlements are barred. But trails and temporary shelters, which were common long before the advent of the white race, are entirely permissible.

When Columbus effected his immortal debarkation, he touched upon a wilderness which embraced virtually a hemisphere. The philosophy that progress is proportional to the amount of alteration imposed upon nature never seemed to have occurred to the Indians. Even such tribes as the Incas, Aztecs and Pueblos made few changes in the environment in which they were born. "The land and all that it bore they treated with consideration; not attempting to improve it, they never desecrated it."[2] Consequently, over billions of acres the aboriginal wanderers still spun out their peripatetic careers, the wild animals still browsed in unmolested meadows and the forests still grew and moldered and grew again precisely as they had done for undeterminable centuries.

It was not until the settlement of Jamestown in 1607 that there appeared the germ for that unabated disruption of natural conditions which has characterized all subsequent American history. At first expansion was very slow. The most intrepid seldom advanced further from their neighbors than the next drainage. At the time of the Revolution the zone of civilization was still practically confined to a narrow belt lying between the Atlantic Ocean and the Appalachian valleys. But a quarter of a century later, when the Louisiana Purchase was consummated, the outposts of civilization had reached the Mississippi, and there were foci of colonization in half a dozen localities west of the Appalachians, though the unbroken line of the frontier was east of the mountains.[3]

It was yet possible as recently as 1804 and 1805 for the Lewis and Clark Expedition to cross two thirds of a continent without seeing any culture more ad-

[1] Webster's New International Dictionary.

[2] Willa Cather, "Death Comes for the Archbishop."

[3] Frederic L. Paxson, "History of the American Frontier."

vanced than that of the Middle Stone Age. The only routes of travel were the uncharted rivers and the almost impassable Indian trails. And continually the expedition was breaking upon some "truly magnificent and sublimely grand object, which has from the commencement of time been concealed from the view of civilized man."[4]

This exploration inaugurated a century of constantly accelerating emigration such as the world had never known. Throughout this frenzied period the only serious thought ever devoted to the wilderness was how it might be demolished. To the pioneers pushing westward it was an enemy of diabolical cruelty and danger, standing as the great obstacle to industry and development. Since these seemed to constitute the essentials for felicity, the obvious step was to excoriate the devil which interfered. And so the path of empire proceeded to substitute for the undisturbed seclusion of nature the conquering accomplishments of man. Highways wound up valleys which had known only the footsteps of the wild animals; neatly planted gardens and orchards replaced the tangled confusion of the primeval forest; factories belched up great clouds of smoke where for centuries trees had transpired toward the sky, and the ground-cover of fresh sorrel and twinflower was transformed to asphalt spotted with chewing-gum, coal dust and gasoline.

To-day there remain less than twenty wilderness areas of a million acres, and annually even these shrunken remnants of an undefiled continent are being despoiled. Aldo Leopold has truly said:

> The day is almost upon us when canoe travel will consist in paddling up the noisy wake of a motor launch and portaging through the back yard of a summer cottage. When that day comes canoe travel will be dead, and dead too will be a part of our Americanism. . . . The day is almost upon us when a pack train must wind its way up a graveled highway and turn out its bell mare in the pasture of a summer hotel. When that day comes the pack train will be dead, the diamond hitch will be merely a rope and Kit Carson and Jim Bridger will be names in a history lesson.[5]

Within the next few years the fate of the wilderness must be decided. This is a problem to be settled by deliberate rationality and not by personal prejudice. Fundamentally, the question is one of balancing the total happiness which will be obtainable if the few undesecrated areas are perpetuated against that which will prevail if they are destroyed. For this purpose it will be necessary: first, to consider the extraordinary benefits of the wilderness; second, to enumerate the drawbacks to undeveloped areas; third, to evaluate the relative importance of these conflicting factors, and finally, to formulate a plan of action.

II

The benefits which accrue from the wilderness may be separated into three broad divisions: the physical, the mental and the esthetic.

Most obvious in the first category is the contribution which the wilderness makes to health. This involves something more than pure air and quiet, which are also attainable in almost any rural situation. But toting a fifty-pound pack over an abominable trail, snowshoeing across a blizzard-swept plateau or scaling some jagged pinnacle which juts far above timber all develop a body distinguished by a soundness, stamina and élan unknown amid normal surroundings.

[4] Reuben G. Thwaites, "Original Journals of the Lewis and Clark Expedition, 1804–1806," June 13, 1805.

[5] Aldo Leopold, "The Last Stand of the Wilderness," *American Forests and Forest Life*, October, 1925.

More than mere heartiness is the character of physical independence which can be nurtured only away from the coddling of civilization. In a true wilderness if a person is not qualified to satisfy all the requirements of existence, then he is bound to perish. As long as we prize individuality and competence it is imperative to provide the opportunity for complete self-sufficiency. This is inconceivable under the effete superstructure of urbanity; it demands the harsh environment of untrammeled expanses.

Closely allied is the longing for physical exploration which bursts through all the chains with which society fetters it. Thus we find Lindbergh, Amundsen, Byrd gaily daring the unknown, partly to increase knowledge, but largely to satisfy the craving for adventure. Adventure, whether physical or mental, implies breaking into unpenetrated ground, venturing beyond the boundary of normal aptitude, extending oneself to the limit of capacity, courageously facing peril. Life without the chance for such exertions would be for many persons a dreary game, scarcely bearable in its horrible banality.

It is true that certain people of great erudition "come inevitably to feel that if life has any value at all, then that value comes in thought,"[6] and so they regard mere physical pleasures as puerile inconsequences. But there are others, perfectly capable of comprehending relativity and the quantum theory, who find equal ecstacy in non-intellectual adventure. It is entirely irrelevant which view-point is correct; each is applicable to whoever entertains it. The important consideration is that both groups are entitled to indulge their penchant, and in the second instance this is scarcely possible without the freedom of the wilderness.

[6] Joseph Wood Krutch, "The Modern Temper."

III

One of the greatest advantages of the wilderness is its incentive to independent cogitation. This is partly a reflection of physical stimulation, but more inherently due to the fact that original ideas require an objectivity and perspective seldom possible in the distracting propinquity of one's fellow men. It is necessary to "have gone behind the world of humanity, seen its institutions like toadstools by the wayside."[7] This theorizing is justified empirically by the number of America's most virile minds, including Thomas Jefferson, Henry Thoreau, Louis Agassiz, Herman Melville, Mark Twain, John Muir and William James, who have felt the compulsion of periodical retirements into the solitudes. Withdrawn from the contaminating notions of their neighbors, these thinkers have been able to meditate, unprejudiced by the immuring civilization.

Another mental value of an opposite sort is concerned not with incitement but with repose. In a civilization which requires most lives to be passed amid inordinate dissonance, pressure and intrusion, the chance of retiring now and then to the quietude and privacy of sylvan haunts becomes for some people a psychic necessity. It is only the possibility of convalescing in the wilderness which saves them from being destroyed by the terrible neural tension of modern existence.

There is also a psychological bearing of the wilderness which affects, in contrast to the minority who find it indispensable for relaxation, the whole of human kind. One of the most profound discoveries of psychology has been the demonstration of the terrific harm caused by suppressed desires. To most of mankind a very powerful desire is the appetite for adventure. But in an age of

[7] Henry David Thoreau, "Journals," April 2, 1852.

machinery only the extremely fortunate have any occasion to satiate this hankering, except vicariously. As a result people become so choked by the monotony of their lives that they are readily amenable to the suggestion of any lurid diversion. Especially in battle, they imagine, will be found the glorious romance of futile dreams. And so they endorse war with enthusiasm and march away to stirring music, only to find their adventure a chimera, and the whole world miserable. It is all tragically ridiculous, and yet there is a passion there which can not be dismissed with a contemptuous reference to childish quixotism. William James has said that "militarism is the great preserver of ideals of hardihood, and human life with no use for hardihood would be contemptible."[8] The problem, as he points out, is to find a "moral equivalent of war," a peaceful stimulation for the hardihood and competence instigated in bloodshed. This equivalent may be realized if we make available to every one the harmless excitement of the wilderness. Bertrand Russell has skilfully amplified this idea in his essay on "Machines and the Emotions." He expresses the significant conclusion that "many men would cease to desire war if they had opportunities to risk their lives in Alpine climbing."[9]

IV

In examining the esthetic importance of the wilderness I will not engage in the unprofitable task of evaluating the preciousness of different sorts of beauty, as, for instance, whether an acronical view over the Grand Canyon is worth more than the Apollo of Praxiteles. For such a rating would always have to be based on a subjective standard, whereas the essential for any measure is impersonality. Instead of such useless metaphysics I shall call attention to several respects in which the undisputed beauty of the primeval, whatever its relative merit, is distinctly unique.

Of the myriad manifestations of beauty, only natural phenomena like the wilderness are detached from all temporal relationship. All the beauties in the creation or alteration of which man has played even the slightest rôle are firmly anchored in the historic stream. They are temples of Egypt, oratory of Rome, painting of the Renaissance or music of the Classicists. But in the wild places nothing is moored more closely than to geologic ages. The silent wanderer crawling up the rocky shore of the turbulent river could be a savage from some prehistoric epoch or a fugitive from twentieth century mechanization.

The sheer stupendousness of the wilderness gives it a quality of intangibility which is unknown in ordinary manifestations of ocular beauty. These are always very definite two or three dimensional objects which can be physically grasped and circumscribed in a few moments. But "the beauty that shimmers in the yellow afternoons of October, who ever could clutch it."[10] Any one who has looked across a ghostly valley at midnight, when moonlight makes a formless silver unity out of the drifting fog, knows how impossible it often is in nature to distinguish mass from hallucination. Any one who has stood upon a lofty summit and gazed over an inchoate tangle of deep canyons and cragged mountains, of sunlit lakelets and black expanses of forest, has become aware of a certain giddy sensation that there are no distances, no measures, simply unrelated matter rising and falling without any analogy to the banal geometry of breadth, thickness and height. A fourth dimension of immensity is added which makes the location of some dim elevation outlined against the sunset as incom-

[8] William James, "The Moral Equivalent of War."

[9] Bertrand Russell, "Essays in Scepticism."

[10] Ralph Waldo Emerson, "Nature."

mensurable to the figures of the topographer as life itself is to the quantitative table of elements which the analytic chemist proclaims to constitute vitality.

Because of its size the wilderness also has a physical ambiency about it which most forms of beauty lack. One looks from outside at works of art and architecture, listens from outside to music or poetry. But when one looks at and listens to the wilderness he is encompassed by his experience of beauty, lives in the midst of his esthetic universe.

A fourth peculiarity about the wilderness is that it exhibits a dynamic beauty. A Beethoven symphony or a Shakespearean drama, a landscape by Corot or a Gothic cathedral, once they are finished become virtually static. But the wilderness is in constant flux. A seed germinates, and a stunted seedling battles for decades against the dense shade of the virgin forest. Then some ancient tree blows down and the long-suppressed plant suddenly enters into the full vigor of delayed youth, grows rapidly from sapling to maturity, declines into the conky senility of many centuries, dropping millions of seeds to start a new forest upon the rotting débris of its own ancestors, and eventually topples over to admit the sunlight which ripens another woodland generation.

Another singular aspect of the wilderness is that it gratifies every one of the senses. There is unanimity in venerating the sights and sounds of the forest. But what are generally esteemed to be the minor senses should not be slighted. No one who has ever strolled in springtime through seas of blooming violets, or lain at night on boughs of fresh balsam, or walked across dank holms in early morning can omit odor from the joys of the primordial environment. No one who has felt the stiff wind of mountaintops or the softness of untrodden sphagnum will forget the exhilaration experienced through touch. "Nothing ever tastes as good as when it's cooked in the woods" is a trite tribute to another sense. Even equilibrium causes a blithe exultation during many a river crossing on tenuous foot log and many a perilous conquest of precipice.

Finally, it is well to reflect that the wilderness furnishes perhaps the best opportunity for pure esthetic enjoyment. This requires that beauty be observed as a unity, and that for the brief duration of any pure esthetic experience the cognition of the observed object must completely fill the spectator's cosmos. There can be no extraneous thoughts—no question about the creator of the phenomenon, its structure, what it resembles or what vanity in the beholder it gratifies. "The purely esthetic observer has for the moment forgotten his own soul";[11] he has only one sensation left and that is exquisiteness. In the wilderness, with its entire freedom from the manifestations of human will, that perfect objectivity which is essential for pure esthetic rapture can probably be achieved more readily than among any other forms of beauty.

V

But the problem is not all one-sided. Having discussed the tremendous benefits of the wilderness, it is now proper to ponder upon the disadvantages which uninhabited territory entails.

In the first place, there is the immoderate danger that a wilderness without developments for fire protection will sooner or later go up in smoke and down in ashes.

A second drawback is concerned with the direct economic loss. By locking up wilderness areas we as much as remove from the earth all the lumber, minerals, range land, water-power and agricultural possibilities which they contain. In the face of the tremendous demand

[11] Irwin Edman, "The World, the Arts and the Artist."

for these resources it seems unpardonable to many to render nugatory this potential material wealth.

A third difficulty inherent in undeveloped districts is that they automatically preclude the bulk of the population from enjoying them. For it is admitted that at present only a minority of the genus *Homo* cares for wilderness recreation, and only a fraction of this minority possesses the requisite virility for the indulgence of this desire. Far more people can enjoy the woods by automobile. Far more would prefer to spend their vacations in luxurious summer hotels set on well-groomed lawns than in leaky, fly-infested shelters bundled away in the brush. Why then should this majority have to give up its rights?

VI

As a result of these last considerations the irreplaceable values of the wilderness are generally ignored, and a fatalistic attitude is adopted in regard to the ultimate disappearance of all unmolested localities. It is my contention that this outlook is entirely unjustified, and that almost all the disadvantages of the wilderness can be minimized by forethought and some compromise.

The problem of protection dictates the elimination of undeveloped areas of great fire hazard. Furthermore, certain infringements on the concept of an unsullied wilderness will be unavoidable in almost all instances. Trails, telephone lines and lookout cabins will have to be constructed, for without such precaution most forests in the west would be gutted. But even with these improvements the basic primitive quality still exists: dependence on personal effort for survival.

Economic loss could be greatly reduced by reserving inaccessible and unproductive terrain. Inasmuch as most of the highly valuable lands have already been exploited, it should be easy to confine a great share of the wilderness tracts to those lofty mountain regions where the possibility of material profit is unimportant. Under these circumstances it seems like the grossest illogicality for any one to object to the withdrawal of a few million acres of low-grade timber for recreational purposes when one hundred million acres of potential forest lie devastated.[12] If one tenth portion of this denuded land were put to its maximum productivity, it could grow more wood than all the proposed wilderness areas put together. Or if our forests, instead of attaining only 22 per cent. of their possible production,[13] were made to yield up to capacity, we could refrain from using three quarters of the timber in the country and still be better off than we are to-day. The way to meet our commercial demands is not to thwart legitimate divertisement, but to eliminate the unmitigated evils of fire and destructive logging. It is time we appreciated that the real economic problem is to see how little land need be employed for timber production, so that the remainder of the forest may be devoted to those other vital uses incompatible with industrial exploitation.

Even if there should be an underproduction of timber, it is well to recall that it is much cheaper to import lumber for industry than to export people for pastime. The freight rate from Siberia is not nearly as high as the passenger rate to Switzerland.

What small financial loss ultimately results from the establishment of wilderness areas must be accepted as a fair price to pay for their unassessable preciousness. We spend about twenty-one billion dollars a year for entertainment of all sorts.[14] Compared with this there

[12] George P. Ahern, "Deforested America," Washington, D. C.

[13] U. S. Department of Agriculture, "Timber, Mine or Crop?"

[14] Stuart Chase, "Whither Mankind?"

is no significance to the forfeiture of a couple of million dollars of annual income, which is all that our maximum wilderness requirements would involve. Think what an enormously greater sum New York City alone sacrifices in the maintenance of Central Park.

But the automobilists argue that a wilderness domain precludes the huge majority of recreation-seekers from deriving any amusement whatever from it. This is almost as irrational as contending that because more people enjoy bathing than art exhibits therefore we should change our picture galleries into swimming pools. It is undeniable that the automobilist has more roads than he can cover in a lifetime. There are upward of 3,000,000[15] miles of public highways in the United States, traversing many of the finest scenic features in the nation. Nor would the votaries of the wilderness object to the construction of as many more miles in the vicinity of the old roads, where they would not be molesting the few remaining vestiges of the primeval. But when the motorists also demand for their particular diversion the insignificant wilderness residue, it makes even a Midas appear philanthropic.

> Such are the differences among human beings in their sources of pleasure, that unless there is a corresponding diversity in their modes of life, they neither obtain their fair share of happiness, nor grow up to the mental, moral and esthetic stature of which their nature is capable. Why then should tolerance extend only to tastes and modes of life which extort acquiescence by the multitude of their adherents?[16]

It is of the utmost importance to concede the right of happiness also to people who find their delight in unaccustomed ways. This prerogative is valid even though its exercise may encroach slightly on the fun of the majority, for there is a point where an increase in the joy of the many causes a decrease in the joy of the few out of all proportion to the gain of the former. This has been fully recognized not only by such philosophers of democracy as Paine, Jefferson and Mill, but also in the practical administration of governments which spend prodigious sums of money to satisfy the expensive wants of only a fragment of the community. Public funds which could bring small additional happiness to the mobility are diverted to support museums, art galleries, concerts, botanical gardens, menageries and golf-links. While these, like wilderness areas, are open to the use of every one, they are vital to only a fraction of the entire population. Nevertheless, they are almost universally approved, and the appropriations to maintain them are growing phenomenally.

VII

These steps of reasoning lead up to the conclusion that the preservation of a few samples of undeveloped territory is one of the most clamant issues before us today. Just a few years more of hesitation and the only trace of that wilderness which has exerted such a fundamental influence in molding American character will lie in the musty pages of pioneer books and the mumbled memories of tottering antiquarians. To avoid this catastrophe demands immediate action.

A step in the right direction has already been initiated by the National Conference on Outdoor Recreation,[17] which has proposed twenty-one possible wilderness areas. Several of these have already been set aside in a tentative way by the Forest Service; others are undergoing more careful scrutiny. But this only represents the incipiency of what ought to be done.

[15] "The World Almanac," 1929.

[16] John Stuart Mill, "On Liberty."

[17] National Conference on Outdoor Recreation, "Recreation Resources of Federal Lands," Washington, D. C.

A thorough study should forthwith be undertaken to determine the probable wilderness needs of the country. Of course, no precise reckoning could be attempted, but a radical calculation would be feasible. It ought to be radical for three reasons: because it is easy to convert a natural area to industrial or motor usage, impossible to do the reverse; because the population which covets wilderness recreation is rapidly enlarging and because the higher standard of living which may be anticipated should give millions the economic power to gratify what is to-day merely a pathetic yearning. Once the estimate is formulated, immediate steps should be taken to establish enough tracts to insure every one who hungers for it a generous opportunity of enjoying wilderness isolation.

To carry out this program it is exigent that all friends of the wilderness ideal should unite. If they do not present the urgency of their view-point the other side will certainly capture popular support. Then it will only be a few years until the last escape from society will be barricaded. If that day arrives there will be countless souls born to live in strangulation, countless human beings who will be crushed under the artificial edifice raised by man. There is just one hope of repulsing the tyrannical ambition of civilization to conquer every niche on the whole earth. That hope is the organization of spirited people who will fight for the freedom of the wilderness.

ON TO THE CITY, FARMER!

By T. SWANN HARDING

MOUNT RAINIER, MARYLAND

HEYWOOD BROUN, in one of his rather frequently vouchsafed moments of inspiration, remarked not long ago that the American farmer was a man who arose at five o'clock in the morning in order to produce more wheat than he could possibly sell so as to get poorer each year. As a remedy for this grave situation he suggested that farmers meet in solemn conclave, agree unanimously to lie in bed till ten o'clock each morning and thus cut wheat production to the point where a high price level could be maintained. If Broun was seeking to play fool at that time it must be remarked that the fool in his folly sometimes knoweth wisdom.

We have in America evolved a tremendous machine designed to emphasize a back-to-the-farm movement and, at the same time, to make agriculture vastly more efficient. From the president down this back-to-the-farm gospel has been hammered into us for generations—the idea that our national prosperity is built upon a sturdy yeomanry or peasantry and that the trend to the cities will ultimately be the death of us as a great self-sustaining organization. In spite of these high-pressure endeavors on the part of statesmen, scientists, economists, social reformers, educators and the press it is conservatively estimated that only about one eighth, or 800,000, of our 6,500,000 farmers have actually taken advantage of the best scientific methods and the most up-to-date agricultural machinery available.

The American farmer remains predominantly inefficient and teeters chronically on the brink of destitution and ruin. In spite of this fact one of his greatest difficulties is undeniably overproduction! To-day the Farm Board "believes that it can be of great assistance to the American farmers by encouraging the development of large-scale, central cooperative organizations." Already 2,000,000 farmers, or nearly one third of the total, belong to the 12,500 existing cooperative associations. It nevertheless remains a fact that this—whether it eventuate in cooperative marketing or more efficiently organized productive methods—will inevitably stimulate production and compel the American farmer to arise still later in the morning to prevent a disastrous depression of price levels. Even as things are, the slightest overemphasis by Department of Agriculture authorities can at any time create dangerous gluts of various farm products and subsequent heavy losses.

Let us examine this problem a little more in detail, adducing in the process a few stray bits of informative evidence. A recent U. S. Department of Agriculture circular addressed itself to the problem of the "Farm Real Estate Situation." It noted, in 1928, a general decline to four fifths of the pre-war value, all economic factors considered. The actual purchasing power of farm products was 93 to 95 per cent. of the pre-war value, whereas the taxes on farm real estate rose to 258 per cent. of the pre-war level in 1927 as against 253 per cent. and 250 per cent. in 1926 and 1925 respectively. It was shown that values have fallen faster than earnings; that the multitude of foreclosed and "distressed" farms still further depressed values, and that, in summary, while the composite farm price of thirty major products was one third above pre-war level, taxes stood at 2½ times pre-war level, machin-

ery was twice as costly and building materials and wages of farm labor were two thirds above pre-war level. The farmer's acute economic predicament becomes apparent.

On top of this the farmer does not know his production costs or how far behind he gets anyway, according to Dean Robert Stewart, of the University of Nevada School of Agriculture. In 1919, for instance, the cost of wheat production was studied by the Department of Agriculture in the states of Kansas, Missouri, Nebraska, Minnesota, North Dakota and South Dakota, and although the cost for winter wheat averaged $1.87 per bushel to produce, the range was from $1 to $8.20 a bushel! The spring wheat average was $2.65 per bushel and the range $1.10 to $14.40. What was a fair, actual, scientific cost of production? Who knows?

In December, 1928, O. E. Reed, chief of the Bureau of Dairy Industry, remarked that a cow producing 100 pounds of butter-fat per year returned only $14 to the farmer over its cost to keep, while if it produced 500 pounds of butter-fat it would give as good an income as thirteen low-grade animals, or $178. One good cow will, therefore, supply 500 pounds of butter-fat for market, but thirteen cows which yield a total of only 1,300 pounds of butter-fat annually, at the same money income value, continue to be kept on many farms and inefficiently produce surpluses with potentialities of economic unbalance. This is further evidence of farm inefficiency.

In June, 1929, C. W. Larson, former chief of the Bureau of Dairy Industry, was quoted in the *Monthly Labor Review* of the Department of Labor as saying that cows producing 9,000 pounds of milk annually, which is twice the average production for the country—in spite of the fact that really good cows to-day produce from 27,000 to 35,000 pounds—eat only 40 per cent. more than animals which produce but 4,500 pounds annually. The average life of a dairy cow is seven years. From 1921 to 1927 our milk consumption increased 30,000,000,000 pounds; this would have required an increased cow population of 6,000,000, yet our cow census on January 1, 1927, showed but 21,948,000 such animals, or an increase of only 160,000 over the 1921 figures, a saving of 5,840,000 cows. This both illustrates present-day farming inefficiency and gives an inkling of what might be expected if efficiency ruled. For if the milk production of the average cow increased but 100 pounds annually, we could continue to supply a two-million increase in our human population with milk for forty years without increasing the number of our dairy cattle, and we should then have raised average production only to the point of 8,500 pounds per animal, which is one third or one fourth of the annual production of the best animals now living.

Again, in the *Nation's Business* for June, 1929, Charles H. Leber, an ex-farmer, called striking attention to the fact that

> Dairying is rightly regarded as a sound and mildly profitable part of our agricultural scheme. Still, within the last fifteen years, multitudes of fairly good dairymen have been forced to abandon dairying as unprofitable. In the face of this fact, seemingly gullible souls have bought herds and have made them pay for themselves besides making a living for their owners. Two and one half years ago a young man of my acquaintance was employed as a milker by two brothers. After five years of dairying the brothers took account of their assets, found that they were standing still financially and decided to throw up the sponge. They offered the herd of forty cows for sale for $5,000, and the farm for rent at $150 a month, $1,500 cash and the balance by the month, over a period of three years. My young friend had $1,700. A deal was made, and the erstwhile employee now has his herd paid for and the boarders replaced by profitable cows, besides having paid for a $700 milking machine and a good deal of miscellaneous equipment.

The same tale of inefficiency and the remarkable productive results which fol-

low scientific methods may be told elsewhere. Mr. Leber continues:

> Ten years ago, a poultry raiser called his foreman into his office and offered him a quit claim deed and bill of sale to land, buildings and the 4,000 hens on the place if he would assume all liabilities. To-day that foreman has a 7,000 bird flock, doesn't pay one cent of interest and discounts his current bills.

Yet as an indication of the phenomenal slowness with which the most obvious scientific methods force themselves upon the attention of farmers, consider this from *Wallace's Farmer* for October, 1928. It was stated therein that Iowa, with a three hundred million dollar swine business aggregating 40 per cent. of the total cash income of the Iowa farmer, actually had no swine association to coordinate production with consumption and to see that swine were reared scientifically and in proper number. An industry like General Motors or the General Electric would have begun to spend a million annually on a project so important years ago.

Again we find *Farm and Ranch* for August 10, 1929, uttering this plaint because farmers will not heed government bulletins:

> The government can give producers valuable information, but it can not make them take advantage of it. Let us call attention to the report on hogs. One was recently issued that fewer sows had been bred in this country than for several years; that cold-storage pork supplies were down; that the pig crop was small, and therefore there was reason to believe that the low point in the cycle of prices had been reached, and for another year prices would be apt to advance. How many farmers will take advantage of this state of affairs and make some money on hogs? This is what a lot of them will do: they will wait until prices start going up. They will hesitate some more and keep on hesitating until prices have about reached the high point. Suddenly they will decide that there is money in hogs and start raising a few. It will take them six months to get a litter ready for the market if they follow the approved rules of feeding and management, and longer if they don't. Thousands of farmers will do this and all will get on the market at once and break it. Prices start down because of the sudden increase in supply. Then those farmers will sell all they have, including their brood sows, and swear there is no money in hogs and never has been. They will go back into the business again about the same way and go broke again.

Returning to wheat—forty years ago the average annual production per acre in the United States was twelve bushels; now it is sixteen bushels. The figures for a few other countries where intensive agriculture has been developed scientifically are: United Kingdom, 32.4; Germany, 31.7; France, 19.1, and the Shantung Province in China, 42 bushels! (Damned clever these Chinese.) Nevertheless, conditions in this country are improving and we may catch up to the high Chinese standard of production after all. What we shall do when we get there is another matter deferred for consideration later herein.

In 1925 ten farm workers could do the work which required twelve in 1920 and fourteen in 1910. In colonial times, according to L. E. Call, of the Kansas Agricultural Experiment Station, 95 per cent. of all American producers were farmers, yet they scarcely clothed or fed their families. At that time our rural population was 96 per cent. of the whole; in 1880 it had dropped to 71 per cent.; in 1890 to 65 per cent.; in 1900 to 60 per cent.; in 1910 to 50 per cent.; in 1920 to 48 per cent., and on January 1, 1927, the Department of Agriculture estimated that but 24 per cent. of our people actually lived on farms. What did this disastrous trek to the city mean? In view of the back-to-the-farm fanatics our situation must have been desperate.

Not at all. Why? Because between 1917 and 1927 agricultural production increased 50 per cent. more than our population increased, and this was done on a stationary or perhaps a decreased acreage under cultivation. A human being as such develops but one sixth to

one tenth horse-power and requires sustenance of the highest grade besides. The agricultural use of horses increased the power in the control of man eight to ten times. But in 1918 Kansas alone had 5,400 tractors and in 1928 it had 50,000 in operation on its farms. Seventy-five years ago human and horse labor enabled a farmer to care for twelve acres of crop land; with modern farm equipment he can care for thirty-four acres, a 300 per cent. increase, and in some places, with the very best labor-saving devices, 300 acres may be cared for by a single man! Thus one man can do as much as twenty-five average farmers of seventy-five years ago, and we begin to ask—why shouldn't there be a migration to the cities and towns and is it so disastrous anyway?

Professor H. B. Walker estimates that if the 1926 Kansas wheat crop had had to be handled as wheat was handled one hundred years ago, it would have required the labor of 775,000 men for twenty days—or the entire male population between fifteen and sixty years of age and all females from twenty to thirty-seven. Three men could, with a little hard liquor, cut, bind and shock an acre of wheat a day a century ago. To-day three men could cut and thresh forty-five acres of wheat in a day and deliver the product to a market two miles away—and that without a shot of anything stronger than sweet cider.

That brings us abruptly to the chain farm idea, which is an increased production method now positively epidemic. It involves cooperative production and marketing under centralized direction, and banks and insurance companies now begin to look kindly upon holding large tracts of farm lands—say thirty-two farms in a tract of 7,500 acres in central Illinois—with each farm operated by a tenant and all under the efficient direction of a general superintendent.

Such a corporation in northwestern Iowa was owned by a group of Davenport business men and operated fourteen farms comprising 3,000 acres. The business was supervised by a full-time general manager. Each farm was handled as a separate unit and a net return of 9.5 per cent. on the investment was secured, a return which makes the individual farmer look a poor second indeed. In the *Illinois Farmer* for January 1, 1929, we read of

> Joseph J. Johnson who for four years has managed thirty-two central Illinois farms comprising 7,500 acres. Each farm pays $1 an acre per year for centralized business management. A bank owns the land and tenants operate the farms. Five-year leases prevail and a five-year permanent agricultural program is laid out. Tenant operators receive half of everything, land owner the other half. In five years, one 320-acre farm shows a net return of $19,620 or 6.13 per cent. on the investment. Mr. Johnson says it costs the average farm $26 to produce forty bushels of corn per acre with average sales price of $28, while the farm above mentioned spent $29 an acre to produce 70 bushels worth $49.

This tells the story of improved scientific efficiency. What of sentimental values? Dr. C. L. Holmes, of the state college at Ames, was reported in *Wallace's Farmer* for January 11, 1929, as saying that "men who work under supervision of this sort in the corn belt are likely to be of greater intelligence than most farmers." When asked what effect corporation farming might have on community life he replied,

> It need not be a poorer community life. On the contrary, it will probably be a richer one. While on the whole it will probably mean a smaller rural population in proportion to the land and capital involved, yet it should be a more intelligent and a more cooperative population, one constituting a better background for the development of worth-while community enterprises and community life.

Here we get a hint of the necessity for an agricultural deflation program in so far as the farm population is concerned numerically. We shall consider that

hint more extensively a little later. Two other instances of efficient farm production intrigue. One is from *Farm and Ranch* for January 26, 1929, and is as follows:

County Agent A. B. Jolley has made a very interesting report relative to the progress being made by the farmers in Dallas County, Texas. Of importance is the fact that the farmers of this county are rapidly learning the value of community standardization of cotton. In the Rowlett community 5,000 acres were planted to a single variety. Six other communities are interested in community selection, and after making tests, it has been decided to make selections for 1929. Mr. Jolley also reports that backland farmers have found it very profitable to grow alfalfa, some of the growers averaging more than six tons per acre over a three-year period. Last year 1,323 bushels of pure-line Denton wheat seed was produced and sold to other farmers at an average profit of $1.50 per bushel over the regular market. This means that a number of other farmers will be growing pure-line Denton wheat in 1929. Many farmers also found it profitable to grow Nortex oats, increasing their yields and the quality of the grain. These oats sold at a profit of fifty cents per bushel over the prevailing market. One Dallas County farmer has developed a Yellow Dent corn that has averaged over sixty bushels per acre in bottom land. . . . Attention is also called to the fact that eighteen registered dairy bulls with high production back of them have been placed among farmers, and that 300 farms in the county have been terraced during the past six years.

The beneficent effect of community enterprise is very self-evident here.

In the southeast corner of Kansas 300,000 people in nine counties have gone unitedly after farm relief on the theory that "the Lord helps those who help themselves" and, perhaps, that the lazy farmer inclined to wait upon Congressional generosity does not deserve assistance anyway. They have created Southeast Kansas, Inc., backed it with money, intelligent management and community enterprise and put it to work to solve their problems. They have made a successful man of affairs chairman and have within their area twenty good towns, forty-eight newspapers, three hundred industrial plants, $60,000,000 in bank deposits, 500 miles of paved city streets and 38,000 home-owners, and they market annually some $50,000,000 of regular farm products, $3,750,000 of poultry and eggs, $3,000,000 of butter and $4,600,000 of milk and ice-cream. Their idea is to promote

sound economy in agriculture, dairying, industry, and to work for better and more efficient markets. Through Southeast Kansas, Inc., we will jointly work for better and more efficient markets. Through Southeast Kansas, Inc., we will jointly work for better drainage, flood control which will serve us in wet as well as in dry seasons, good roads, better schools and for the place in the sun that our region is entitled to occupy. . . . We know that water runs down hill, that well-cultivated and properly fertilized land produces more than undrained, poor land, that competitive markets pay producers more than non-competitive markets do, that good roads and a balanced farm economy are profitable.

In short, these people in Kansas will not only become infinitely better agricultural producers, they will also enrich rural life at the very same time, and will almost inevitably decrease the necessity for a farm population of even the present size.

To-day the farm population of the United States is the smallest in twenty years, according to the Bureau of Agricultural Economics. It was 27,511,000 on January 1, 1929, as compared with a peak of 32,000,000 in 1909. The decrease would have been much greater had it not been in part offset by an excess of births over deaths. Some 1,960,000 persons left farms during the year, although 1,362,000 moved from cities to farms. The movement from the farms slowed up somewhat as compared with immediately preceding years, but the movement from cities to farms was somewhat smaller. Now, is this condition disastrous?

For long years we have constantly been regaled with a back-to-the-farm gospel as our only salvation. This gospel has been consistently dinned into our ears, in spite of the fact that the matter presented above plainly demonstrates the same trend of events in agriculture as in industry—increased production per unit of labor. In industry this situation has already produced a group of workers who are partially or totally unemployed due to the increased efficiency of machine production; the situation there would have been critical had not the automobile, the radio and other new industries come along opportunely to absorb part of the slack.

But we have to-day only about 800,000 efficient farmers. We are doing our best to make the remaining 5,700,000 farmers as efficient as this minority. If we actually accomplish this laudable aim what would happen? Let us again return to wheat to keep the subject as simple as possible. Our annual American production is about 800,000,000 bushels. Remember the low average per acre yield—sixteen bushels as against thirty-two in England and forty-one in Denmark. We export some 200,000,000 bushels of wheat annually. If we assume that we increase our yield per acre of wheat only 50 per cent., which would not be extraordinary, what on earth would we do with the rest of the wheat? It seems Heywood Broun was right.

No great extension of demand is possible. The American citizen is unlikely to be able or willing to eat more wheat—in fact, the modern nutritional tendency is to eat less of everything. Branches of agriculture devoted to the production of human food can not expect much increase in home demand. The export trade in food towards Europe is already declining, and India and China, in spite of recurrent starvation periods, can not afford to buy American wheat at prices satisfactory to American farmers. What is true of wheat is more or less true of all other American agricultural crops. Already the enormous potentialities of scientific agriculture, if put into operation quite generally, could so outstrip consumption that we should be fairly inundated with food if we had 6,500,000 efficient farmers. Under such circumstances a million or less farmers would amply supply us.

In short, the facts force us to believe that agricultural deflation must occur. As farming becomes more efficient some twenty million people must be absorbed by city industry. While this would, if spread over a period of twenty years, be no greater job than the absorption of a million European immigrants annually, which we accomplished regularly before the quota policy was introduced, it would probably present a difficult problem simply because machine production gains annually in efficiency. Nevertheless, it does not look as if there is much hope for these people if they remain on the farm. We may be called upon to cook and eat a few of them, but we certainly can not have them uselessly cluttering up our farms when agriculture becomes as scientific as the Department of Agriculture could make it right now, given proper facilities for distributing the knowledge it has already accumulated.

In 1926 Sir Daniel Hall gave a presidential address on food and population to Section M (Agriculture) of the British Association for the Advancement of Science. He presented data to demonstrate that the average consumption of food and raw material by white peoples requires from 2 to 2.5 acres per head and that, since the white population of the world increases at the rate of five million per annum, there must be a commensurate increase of 12,500,000 acres per annum under cultivation, or else a proportionate increase in yields on the existing acreage, since there are no new

areas worth speaking of to be opened up. It is this intensive agriculture which our Department of Agriculture seeks to inculcate. Next, the concluding paragraph of a brief editorial entitled "The Future of Agriculture" in *Nature* (London) for July 20, 1929, is apposite.

This [Sir Daniel Hall's view], of course, may still remain true as the expression of a general tendency for the greater part of the world which is bound to operate in the long run; but if the American position is really that which has just been described—namely, overproduction even though a great majority of the farmers are producing at a very low level—then it would seem that the general rule enunciated by Sir Daniel Hall appears to be subject to substantial local or temporary checks; although, on the other hand, it is quite possible that the American position has not been quite correctly diagnosed, and certainly some rather large assumptions have been made. One may yet conclude that the bounty of nature and science is far greater than we have ever envisaged in our wildest dreams, that the law of diminishing returns may be suspended almost indefinitely and that there is—and will be for some time—an economic limit to the extent to which the world, as a whole, can employ the mighty powers and resources of modern science in the realm of agriculture.

In other words, the farmers better begin to lie abed longer, as Heywood Broun advised, or they may soon be starving in droves. This would almost certainly clutter up the highways in such manner as seriously to interfere with the progress of automobile tourists and would, therefore, be most objectionable. The only thing left for the farmers to do is go to the city and work in factories. It is said that six pall-bearers were recently conveying the remains of a prominent industrialist down the church aisle when he suddenly came to life and exclaimed: "Put this infernal thing down immediately and get a truck; fire five of those men and let the other one push it." The story, perhaps apocryphal, at least adumbrates the situation the agriculturists will find confronting them in the city, but it would not be possible to speculate what might be done regarding that without making this article entirely too long.

A NEW PSYCHOLOGY AFTER THE MANNER OF EINSTEIN

By Dr. PAUL CHATHAM SQUIRES

CLINTON, NEW YORK

I

In an era marked by such intense interest concerning things psychological as is the present one, many aspects of psychology have found expression in the popular literature. Especially have the problems of sex and the occult found a dominant place in the public mind. But there is a most fascinating chapter in psychology, hitherto unrevealed to the layman, that affords a striking comparison of a new movement in psychology with the principle of relativity made current and popular by the great physicist Einstein.

The essence of that which has been stored in the abstruse treatises of the professional psychologist may readily be grasped by thousands of intelligent readers provided the story is stripped of its academic clothing. And it is the purpose of the following pages to portray in a simple manner the teachings of the youngest member of the psychological family, a new psychology that adopts the spirit of Einstein's approach to the realities of the universe. This new psychology goes by the significant name of the Gestalt psychology, which means in our language the configuration psychology, and is perhaps chiefly remarkable for its intimate connection with modern physics.

The Gestalt psychology, arising in Germany within the course of the past two decades, has been enthusiastically heralded by some as furnishing the one and only adequate key to the problems of mind, while by others it has been made the target of violent criticism. Whatever the final verdict of science in respect to the claims of this new school of psychology may be, configurationism has at any rate succeeded brilliantly in agitating and redirecting the currents of traditional thought. For just as Einstein gave an impetus to physics by expounding the relative nature of space and time, so the champions of the configuration psychology have been assiduously engaged in the attempt to demonstrate the relative character of our mental life, and have thereby imbued present-day psychology at large with renewed vigor.

Every one has a practical understanding of the word configuration. It means the outline, the shape, the contour of an object; thus, we may speak of the configuration of a human face or the configuration of a mountain. And when we are studying the configuration of something we are either ignoring or treating as unimportant for our present purposes the elements, the bricks as it were, which enter into the composition of the given structure.

The use of the term Gestalt or configuration, then, implies that our attention is focused upon the object-considered-as-a-whole, and not upon the object-considered-as-consisting-of-parts. Here you have unearthed the fundamental clue to the secret of the configuration psychology. For this new psychology interests itself primarily, if not exclusively, with the form, rather than with the so-called elements, of mental activity. The older psychology, however, was preoccupied with a highly abstract dissection of mind into its ultimate parts, and hence strongly resembled an atlas of anatomy. Toward this anatomical attitude the configuration psychology is utterly hostile.

The older psychology, with all its talk about "simple sensations" and "pure reflexes," was far removed from the realities of every-day life. Freud brought forward his sex psychology at the turn of the present century, and this, in its many variations, has served as a partial if not always perfectly acceptable antidote to the undue abstractness of the classical psychology.

The development of the mental test represents another one of a number of comparatively recent tendencies toward a more practical and realistic view of human nature. And the American behaviorists have made notable contributions to the cause of evolving a psychology that may more effectively enable us to direct the progress of the individual through his social world. The latest arrival on the scene, the configuration psychology, is endeavoring to carry out a program in which the ordinary meanings encountered in daily existence are made the vehicles of a set of scientific principles that find their parallel in Einstein's doctrine of physical relativity. This is most assuredly a novel undertaking.

II

Let us make the acquaintance of the new relativity psychology by means of a not unusual example taken from the colored moving pictures. Suppose a patch of green to appear somewhere on the cinema screen, and furthermore suppose that, perhaps on account of absent-mindedness, you have as yet attached no definite meaning to this expanse of green. The green so far means neither green water as viewed in the distance nor the green of foliage; it is simply greenness to you and that is about all. Suddenly you come to realize that this patch of green represents, *means,* the blue sky, and instantly thereupon the green is transformed into a fairly natural appearing area of blue sky. Thereafter, no matter how hard you try to change the blue back into green, you will fail. Here we observe one of the operations of the law of psychological relativity. The traditional psychology taught that a color possesses a more or less absolute, unchanging character. Green, for instance, according to this older mode of thinking, should be green anywhere, regardless of the meaning which it bears. But the simple observation just described would seem to show conclusively that color quality is a matter relative to the meaning borne by the quality.

Again, when we try to estimate the amount of redness cast upon a snow field by the rising or setting sun, it has been experimentally determined that we consistently underestimate the amount of redness present. The mind makes allowance unconsciously for the fact that snow is white and the redness diffused over it by the sun is accidental only, is merely in temporary connection with it. The meaning of snow has a powerful effect in forcing the observer to perceive a less amount of reddish tinge than he would see provided this meaning were absent. You can demonstrate this fact to yourself sometime by first gazing at the snow in the ordinary manner and then by looking at a restricted extent of it through a paper or cardboard tube. When you look through the tube be sure to eradicate as completely as you can the meaning of snow, to which over a long course of experience you have come to attribute a highly stable whiteness. This is to say, get the color-meaning of snow to lapse from consciousness. If you are moderately successful in doing so, the limited area surveyed fixedly through the tube will come at last to mean nothing much in particular, and you will discover that a far larger amount of redness is present than is observed under the ordinary conditions. Thus this little experiment gets at the roots of a profound psychological truth; namely, that a quality, whether a

color quality or any other sort of quality, for that matter, depends for its precise character upon the context, upon all the relations, in which it stands. A quality as perceived by us is not absolute but relative.

This doctrine of psychological relativity finds application both to human and animal response. Through the study of animal behavior we frequently gain the advantage of being able to observe the working out of psychological principles in a more primitive, simple manner than is the case at the human level.

Construct in a goldfish tank two wooden compartments, each having an entrance large enough for your goldfish to pass through. Place these compartments side by side and slightly apart at one end of the tank and illuminate each independently by means of an electric light. The electric lights are hooked up with an instrument called a rheostat, which enables the experimenter to control the brightness of each light, raising or lowering the illumination at will. After having darkened the room in which the tank stands, illuminate one compartment with a rather low light intensity which we will designate for convenience intensity *A*, and the other compartment with a somewhat higher intensity *B*.

Now, release a hungry fish at the end of the tank opposite the lights, first having taken care to place some food in the more brightly illuminated compartment. The fish will swim toward the lights and, in the course of its explorations, will pass eventually into the brighter compartment, where it will find food. As soon as the fish has obtained the food repeat the experiment. But this time arrange it so that the brighter light is in the other compartment, in order that the fish may learn to react to this brighter light regardless of its position at right or left. Shift the relative position of the lights in a chance order over a series of trials lasting a number of days, and you will discover that at last the goldfish swims in a direct and speedy manner to the brighter light *B*, without making a single error.

According to the contentions of the older psychology, the goldfish would be said to have learned to respond selectively to the absolute, not the relative, brightness of light *B*. But does it really react in this way? Let us see.

After the training of the fish has been fully established, we now proceed to subject the animal to what is known as the "critical test." This test is conducted by leaving light *B* at its original brightness and raising the intensity of light *A* to an intensity which we will call *C*, the brightness of *C* being somewhat greater than that of *B*.

Bear in mind that the goldfish has been taught to pick out light *B*. But when the fish is presented with the two lights *B* and *C*, it responds without hesitation to the latter light, although the former light was the one which it had learned to choose. Evidently, what the animal was all along responding to was not the light *B* considered by itself, but light *B* as a member of the pair *A B*, of which it was the brighter member. The fish is responding to the brighter of two lights. It is reacting to a light as a component of a total situation. The animal behaves in a relative, not in an absolute, manner. Here we witness the conflict between the older and the newer interpretations in the field of psychology.

The moving picture illusion furnishes us with another example through which may be understood the point of view of the Gestalt psychology. This illusion has attracted much attention as a scientific problem, but it is as yet by no means fully explained. The apparent motion perceived by us is produced by a rapid succession of stationary photographs, but just how this effect is brought about is the question. The more common ex-

planation amounts to about this: that exactly as one can whirl a firebrand around in the darkness so as to obtain the appearance of an unbroken circle of fire, the so-called positive after-image of the flame seen at different positions of the whirl fusing to give the form of the circle, so in the moving picture illusion the effect is produced by a union or fusion of the stationary positive after-images, each one of which means, perhaps, a race-horse in action.

The classical psychology would carry its dissection of the perception of illusory motion to the point where the perception is described as the *outcome* of an addition of stationary visual images. But here the configurationists raise an objection. They have experimented on the illusion under many different conditions and maintain as the result of their investigations that the perception of motion is to be interpreted as one indivisible whole which can not be reduced to such parts as images without incurring the annihilation of the illusion. An anatomical attitude assumed by the observer toward the illusion destroys it.

As an especially forceful line of evidence, the configurationists, and some others for that matter, claim that they have observed the illusion of motion without anything moving. This is one of the paradoxes of science. How can motion be seen apart from some object carrying the motion? Absurd as the notion of "pure motion" may seem, however, there does appear to be sound testimony as to its at least occasional occurrence. If movement can be apprehended as separate from a thing bearing the movement, is not this fact overwhelmingly in favor of the unitary, totalized nature of the movement process and opposed to the idea that the perception of motion is nothing but a summation of after-images and sensations of eye-muscle strain? Whatever may be the ultimate decision concerning the experience of "pure motion," this supposed fact of vision has led to much emphasis upon wholes rather than upon parts, upon unities rather than upon simple elements. And the Gestalt psychology is untiring in its description and explanation of totalities in the field of experience and behavior.

The intimate relation between space and time is being brought home to us constantly. Spatial values are shrinking from year to year. A few hours now suffice for the traveler to span the continent. A giant airship flies around the world in a few days. As speed increases, distance decreases. So we come to say that distance depends on, is a function of, time. As in the practical activities of our daily lives we recognize this fundamental fact of relativity, so the psychological laboratory gives detailed information about it.

Take, for instance, such a simple and yet such an enlightening experiment as the following one. Have some person close his eyes, and then, using the blunt point of a pencil, touch him now at one position and then at another on the back of the hand. If you take care to place the two successive touches always the same distance apart as measured in terms of inches, but vary the rate of the touches, you will find that the person upon whom you are experimenting will report that the greater the rate of stimulation the shorter the apparent distance between the touches. And just as in the case of vision it is possible to produce the illusion of motion, so in the field of touch, if the two stimulations are speeded up, there finally comes a stage where the experience of a mere succession of touches is replaced by the experience of one point in continuous motion over the surface of the skin. So it has also been asserted that there is a most curious illusion of movement in hearing, where two sharp sounds are presented first to one ear and then to the

other with an extremely brief time interval between the sounds. Throughout all these interesting experiences we have the opportunity of observing the complicated interlocking of space and time.

Not only is there a most intricate relation between space and time, but also between these two and the intensity of whatever object may be involved. We say that one light or sound is more intense than another; and the magnitude of an object is a special form of intensity. Quite recently it was discovered by the configurationists that in a simple version of the moving picture illusion the direction of movement of a line, for instance, could be reversed by merely altering the intensity relations between the successively presented pictures. The new psychology has worked out three fundamental laws showing the mathematical relations between space, time and intensity values requisite for obtaining the movement illusion.

This is a truly scientific approach to the problem, and illustrates aptly the method of the configuration school. For this method is based upon the assumption that the knowledge of certain physical properties possessed by the material agents in the world outside of the organism will enable us to predict the nature of the resulting experience and behavior.

But these purely external conditions are not of themselves always and ever sufficient to bring about a desired effect. The attitude of the observer is a matter of no small importance. Unfortunately, psychologists have found the problem of attitude a most tangled one, but progress toward the solution is gradually being made. However, the occasional failure of the three laws just mentioned does not imply the incorrectness of these laws, for there are laws of a "higher order" residing within the one who is doing the reacting.

The explanations of the configuration psychology are couched both in physiological and in physical terms. Take, for instance, the explanation of the illusion of motion advanced by the configurationists. The older and more prevalent account given of the physiological mechanics involved in this illusion has considered absolutely essential the operation of at least two brain levels. We may compare brain levels to the stories of a building, although this analogy has latent in it some very absurd features. The older theory would say that the perception of movement is mediated more particularly by the higher level. The materials entering the lower story from the eyes are in a raw, chaotic state, and it is necessary for the mechanics of the upper story to organize and unify the materials deposited in the lower story before the perception of motion results.

The configuration theory, on the other hand, has speculated on the possibility of the illusion of motion being mediated at the lower brain level, this level doing the entire work. The theory in question invokes a short-circuiting process at the lower brain level, analogous to the short circuit that once in a while occurs in a network of electric wires. The nerves in the brain correspond to the electric wires. This explanation has been set forth by the Gestalt psychologists in terms of the physics of nerve transmission. In fact, as will be pointed out in more detail below, the architecture of the configuration theory emerged out of the abode of modern physics.

III

Primitive man saw in human purpose the expression of the will of good and evil spirits. In nature, the lightning and the whirlwind voiced the wrath of a god. The coming of modern science has enabled us to understand the events of physical nature in terms of natural causes, but the struggle to interpret human action without reference to su-

pernatural agencies has been long drawn out and severe.

Consider the manner in which the configurationist would solve the mysteries of purpose. Cover a section of fine-meshed wire netting with a soap-bubble film. Cast upon this film a loop of thread. In all probability the loop will assume a highly irregular form. Prick the film somewhere within the loop and see what happens. At the moment of pricking, the loop jumps into a shape, a configuration, that shows a strongly circular tendency.

Observing all this, you would not think of saying that the alteration in the form of the loop was brought about by supernatural means. You would seek to explain the fact by reference to surface tensions. Purely physical laws are here active. No genie has directed the shift in form. The little loop of thread has been forced into the shape demanded by the physical law of the expenditure of least possible energy. It has passed into a new state of equilibrium that is in harmony with the change in surrounding conditions, and the tendency has been in the direction of simplification of form, from the irregular to the symmetrical.

The law of least energy, so say the Gestalt psychologists, applies not narrowly to the world of matter but also to the world of mind. Pause for the moment and consider how this law is operative in the fields of perception and memory.

Imagine twelve small white disks against a black background, arranged in such a way that the disks, if joined together by straight lines, would form a regular twelve-sided figure. Now alter this pattern so that any one of the disks is somewhat farther from the center of the figure than the other eleven disks. This alteration has of course destroyed the symmetry of the figure; the pattern now appears to you to be out of balance. If this unbalanced figure is presented for a small fraction of a second a strange thing will be seen to happen. The displaced disk shoots inward toward the position it would occupy were the figure to become a regular, simple, balanced one. Of course, no motion has occurred in the physical sense of that word, but nevertheless the illusion of motion is experienced.

This fact of perception holds many possibilities for a more adequate insight into the nature of mind. Here is to be witnessed the ultimate similarity between the psychological and the physical aspects of the universe. Just as the loop of thread had to pass from a more complex to a simpler form, according to the law of least energy, so did our perception of the unsymmetrical twelve-sided figure undergo a change toward symmetry and simplicity, toward the best possible equilibrium.

Again, show some one a number of irregular and more or less complicated geometric designs. Ask him to study these designs for a few seconds each. Next day have the person draw the figures from memory. Repeat this performance for a few days and compare the results obtained from day to day. The Gestalt psychologists have claimed that these drawings reveal the law of simplification. For, say they, the successive drawings assume more and more simple form, instead of becoming more complex.

These two illustrations taken from perception and memory are samples that have been used to indicate that human behavior and physical events are different expressions of purely natural law. Human conduct, however, on account of its immense complexity, is at first view incomprehensible in terms of natural law. Hence, mankind in general has always dragged in the notion of some undefined, mystic, supernatural Purpose to explain this conduct. The configuration psychology has been a leader in the

scientific movement to close the ancient gap between mind and matter. It has interpreted purposeful activity, the seeking after goals, as a natural, not a supernatural, event. To be sure, the configurationists are not the first to have suggested this type of solution. But they have related human and animal purpose more effectively to the facts and theories of modern physics than have their predecessors.

IV

The standard-bearers of the Gestalt movement are carrying into execution a frontal attack on the great enigmas of mind. They are delving into the problems of sense perception, memory, learning and intelligence. Of late years they have been probing into the mysteries of insanity and the sources and nature of our appreciation of the beautiful. The Gestalt theme with variations is the supreme importance of the total situation and the organism-considered-as-a-whole. Whatever parts may be recognized to exist are not prior to, but grow out of, the original, primal whole. Furthermore, the foundation laws of psychology and physics are identical.

Configurationism and Einstein's doctrine of physical relativity seem to be developing in parallel directions, notwithstanding the fact that the subject-matter of each appears on the surface to be so completely different from that of the other. Einstein protested against the conventional world scheme of Sir Isaac Newton. Einstein begins the story of the physical universe not with such unrealities as absolute space and time but with the account of two bodies in motion relative to each other; he dispenses summarily with a fixed framework of space and time.

For Newton, space and time values are independent of the position of the human observer and are presumed to be identical for every segment of the cosmos. For Einstein, these values depend directly upon the position of the observer. All physical evaluations are purely relative to the particular total situation within which they are calculated. Also, the combination of velocities is not a merely additive matter, but is something more than a straightforward summation. Here we see pronounced the apparently revolutionary proposition that even at the purely physical level the whole is not equal to the sum of the parts.

For the traditional psychology, particular experiences and bits of behavior possess a more or less absolute character. For the Gestalt psychologist, any aspect of mentality has meaning only in its relation to the larger context, the whole, in which it exists. Configurationism begins its narrative with an account of the ordinary meanings of common sense, the wholes of experience, which may be encountered in every-day life. It does not begin with a description of fictitious parts called pure sensations and reflexes.

To the classical psychology, human perception, for instance, is viewed as a mosaic, as a bundle of originally meaningless psychic atoms called simple sensations. For the Gestalt psychology, every perception, whether of a person's face or of anything else, exists in its own right, is itself. The perception is something over and above the sum of its supposed parts.

But the configuration doctrine, in spite of its apparent novelty, owes a big debt to history. What scientific movement does not? Einstein, for that matter, had his predecessors more than two thousand years ago. The configurationists are not the only psychologists to have recognized the idea of psychic relativity, although they are the first to have elaborated the idea into a workable system. The origin of the notion lies in the dim past. Perhaps we might trace its nearer origins to

the founder of experimental psychology, Wilhelm Wundt, of the University of Leipzig. But that is another story. Suffice it to say that the concept of relativity in the domain of mind has been evolving slowly but surely. The configurationists, however, merit the distinction of being the first to develop this concept scientifically.

Mind is the outstanding riddle of the universe. Because of the well-nigh unbelievably great complexity of its subject-matter, psychology has lagged in the rear of the conquering advance of the physical sciences.

But, notwithstanding the manifold difficulties confronting the student of mind, it seems certain that the doctrine of psychological relativity as enunciated by the Gestalt school will lead eventually to a thorough readjustment and advancement of psychology at large. Already can there be detected the beneficial influence of this mode of thinking upon current American and European psychology. Whether or not its chief value will finally be found to consist in its rôle as a method rather than as a point of view is a question that need not detain us here.

Whatever the verdict of posterity may be, the Gestalt psychology has attempted the remarkable feat of giving due tribute both to the common-sense meanings that have always been the property of the ordinary man and to the most inclusive world scheme of all time, the Einstein doctrine of physical relativity.

SOME DEMOGRAPHIC CHARACTERISTICS OF AMERICAN EDUCATIONAL CENTERS

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In the Scientific Monthly for March, 1920, the writer described a method of measuring civilization by means of a graded classification of occupations, based on city directories, alumni catalogues, etc. Since that time there have been published the reports of the 1920 census of the United States, which analyze the returns more minutely than previous censuses and afford some additional measures of civilization, which though indirect are simple to apply and can be had for every county and city in the country.

Civilization, or aristocracy, may be based on either wealth or culture. These things of course are not synonymous, and one can easily find individuals who have a good share of one and not much of the other, but in a whole city, country or state they generally go together pretty well. The U. S. Census Bureau has published statistics of per capita wealth, incomes, etc., at various times, but they are subject to differences of interpretation, and do not mean much for areas smaller than states, for persons living in one city or county may own considerable property in another.

An indirect index of wealth is afforded by the age distribution of the population, which may be expressed in average or median age, proportion of persons under ten or over twenty-one (or any other age), or size of families. For most adults are breadwinners and most children are not, and consequently a community with a large proportion of adults is pretty sure to be more prosperous than the other extreme; and the increase in per capita wealth in all civilized countries in the last hundred years or so may be ascribed largely if not mostly to the well-known decrease in the size of families. In the United States at the present time the adult percentages range from about 40 in some of the mountain counties of Kentucky and Virginia to 75 in Palm Beach, Florida; and they are tending to increase everywhere as the expectation of life is prolonged by medical science.

From 1830 to 1860 one can get from census reports the number of persons under ten or twenty, and the approximate number of adults, in every county. For the censuses of 1870 to 1910 inclusive most such data are given for states but not for counties, though in 1910 the number of persons under ten in each county and city can be ascertained from the illiteracy figures. For 1920 the age statistics for counties are more satisfactory.

The greater the proportion of adults of course the fewer the children, and therefore the smaller the families—for few families have more than two or three adults, while the number of children may range from none to a dozen or more. Not only the total number of persons per family is of interest, but also the number of men, women and children separately. (For counties and cities such data are available in 1920 more completely than ever before, though families of different races were not separated then as well as they were in 1910.) The number of men and women per family is an index of the average age of marriage. For if it was customary for every one to marry and start a new family at the age of twenty-one there would be just about one man and one woman per family, the oc-

casional loss of husband or wife being just about balanced by cases of old people living with their married children. But if a young man or woman remains single for awhile after passing twenty-one, then he (or she) is an extra adult in some family, either that of his parents or in a boarding-house somewhere else.

It is well known that people marry a little later in the North than in the South, and in the city than in the country, and whites later than Negroes, and these tendencies are reflected unmistakably in the number of men and women per family in different communities or races. But in the whole United States the number of men and women per family, and therefore presumably the average age of marriage, has changed very little since 1850; and in single states and smaller areas the averages are probably also reasonably constant from one decade to another, unless the character of the population is changed by migration.

The most direct measure of civilization afforded by our census statistics is the illiteracy count, which has been given for various population groups in every census since 1840, and for 1920 is available for adult males and females (and some other age groups) in every city and county. It is a rather crude measure, for it lumps together college graduates and people who can barely read and write, but when used in connection with other measures of either wealth or culture it shows a fair degree of correlation.[1]

Another fairly good indirect index of culture, which has been very little used, is the sex ratio. For males are generally greatly in excess in such primitive communities as mining and lumber camps and cattle ranches, and moderately so in city slums, while females generally predominate in college towns, summer resorts, etc.[2]

Useful indexes obtainable from other sources than the census are the detailed circulation figures for various magazines that appeal to intelligent people, and the ratio of noted persons (typified by names in "Who's Who in America") to total population, adult population or families.

The use of such statistics to measure civilization will now be illustrated by a study of twenty-five educational centers, in seventeen states, scattered from Massachusetts to California. The cities selected are as far as possible those in which a college or university (or sometimes more than one such institution) is the dominant factor in the life of the community. Some college towns also contain factories, employing large numbers of people who need very little education in their business, and these (with two or three exceptions which will be mentioned) are excluded from the study. Those with less than 80 per cent of their population white are also excluded, to minimize possible complications due to racial differences. It is also necessary to confine the study to municipalities with at least 2,500 inhabitants, for recent censuses give no information about the smaller places except the total number of inhabitants.

For these reasons all college towns south of West Virginia and east of Arkansas are excluded, for they are all either too small or have too many factories or Negroes to be typical. Some which seem to measure up to the re-

[1] Some educators or uplifters profess to regard illiteracy as a symptom not of lack of culture but of lack of opportunity; and they hope to "eradicate" it entirely from the United States before the next census, and thus do away with one of our yardsticks of civilization. For all such measures of quality of population seem to be obnoxious to people who make "democracy" a fetish. But there would not be much use trying to have civilization if we could not measure it occasionally and see what progress we are making.

[2] This measure, however, gives contradictory results when applied to different races, for if the census figures are correct the proportion of females is nearly everywhere larger among Negroes (especially mulattoes) than among whites.

quirements in everything except size are Chapel Hill, N. C., and Auburn, Ala. In the ratio of "Who's Who" people to population Chapel Hill seems to be ahead of all other municipalities in the United States, with the possible exception of Princeton, N. J.; and if its population is over 2,500 in 1930, as seems probable, we can then find out some very interesting things about the place.

Some of the colleges in the cities and towns under consideration are for men only, some for women, and some coeducational, but that seems to make little difference in the sex ratios of the communities, for students are supposed to be counted in the census at their homes, rather than where they go to college. (Another plan, which the writer used in the Florida state census of 1925, and which has some obvious advantages, is to make a special enumeration of educational, charitable, penal and military institutions, and tabulate them separately from the counties or cities in which they are located.)

The statistics in the following table are all for January 1, 1920, or the nearest possible date. Of course there have been some changes since, especially in the number of inhabitants, on account of the rapid growth of all our colleges since the World War, but there is no reason to expect that the next census will show any marked changes in the various ratios. The communities represented are first the whole United States and its urban and rural population, for standards of comparison. Then three cities which are too large to be typical educational centers, but are included for special reasons; Washington because it has a very small industrial population, and ranks high in many measures of culture, and New Haven and Cambridge because they are the seats of two of our oldest and largest universities. Washington, unlike all the other places listed, has less than 80 per cent. of its population white, but if statistics had been computed for whites only (as could have easily been done) the results would not have been very different from those here presented.

Finally there are twenty-three cities and towns regarded as typical educational centers, arranged in order of size, and at the bottom the unweighted averages of all the ratios for these twenty-three places. The number of places studied had to be limited in order to economize time and space, but if a larger number or an entirely different list had been used, and true instead of unweighted averages calculated, it might not have made much difference.

The kinds of statistics used are the percentage of whites, males and adults, the number of persons per family (also separating men, women and children), the ratio of children (under twenty-one) to women (over twenty-one),[3] adult illiteracy for both sexes, combined and separately, the percentage of families represented in the 1920 edition of "Who's Who in America" (assuming that there is not more than one such person in a family), and the percentage of "wage-earners" (in factories, in 1919) in the total population. Statistics of magazine circulation and a few other things could have been given if space had permitted, but they would probably show no marked departure from the tendencies here indicated.

About two thirds of the "wage-earners" in Washington are not in regular factories, but in governmental establishments such as the Navy Yard, Bureau of Engraving and Printing and Government Printing Office; but their social significance is essentially the same as if they were in factories operated for profit. The census gives no data on factories and wage-earners for cities with fewer than 10,000 inhabitants, which

[3] For the significance of this ratio see *Jour. Heredity*, 18: 217–223. 1927; 19: 172. 1928.

accounts for the blanks in the lower part of the last column. Neither does it separate white and colored wage-earners; but that makes no difference in the present study.

On examining the table it will be seen that every city in the list, without exception, has more women than men, though this can not be said of most of the states in which they are located.[4] The only ones that have less than 60 per cent. of adults are located on the edge of the South (which has a higher birth-rate than the rest of the country, and therefore a larger proportion of children).

Most of the cities have less than four persons (including less than 1.5 children) per family; and the exceptions, if investigated, would probably be found to be due either to other businesses than education or to a considerable number of unmarried teachers living in boarding-houses (indicated by more men and women per family than the average). From what has been said above about the relation of the number of adults per family to the average age of marriage, it would seem that in comparison with all American cities, the men in college towns tend to marry earlier, this doubtless on account of the opportunities afforded by the surplus of women; while the matrimonial opportunities of women in such communities are correspondingly less. The number of old maids in college towns has long been proverbial; and it would seem from the table that spinsters or widows, or both, must be especially numerous in Washington, Evanston and Wellesley.

The ratio of children to women in college towns averages around 1, as compared with 1.20 for all American cities in 1920, and 1.92 in the rural districts. This would seem to indicate an approximate equality between births and deaths in such places (which may characterize the whole United States about the middle of the present century, if the birth-rate continues to decline as it has been doing in recent decades).

In the whole United States, and especially among foreigners and Negroes, there is more illiteracy among women than among men; but most of the college towns show the opposite tendency, indicating a superior class of women there. The adult illiteracy is greater than some might expect, being seldom less than 1 per cent. in 1920, if the communities selected are typical. But where it is over 3 or 4 per cent. it may be due mostly to foreigners or Negroes who have no connection with educational institutions. Incidentally, the presence of so much illiteracy in educational centers as late as 1920 suggests the futility of the hopes of those who would like to "eradicate" it from the entire nation by 1930.[5]

The "Who's Who" percentages run below 1 in only a few cases. College towns rank far above other communities in this respect, though it might be charged that "Who's Who" includes a disproportionate number of educators and librarians who seldom if ever write for publication and are therefore known only to a small circle of students and friends. The statistics of wage-earners probably need little comment, except to call attention to the footnotes pertaining to the last column.

It would be beyond the scope of the present paper to give similar statistics for communities verging toward the opposite extreme of American civilization, but any reader who is sufficiently inter-

[4] In all the cities with over 10,000 inhabitants listed in the table—and probably also in the smaller ones, though the census gives no such details for them—females are in the majority at all ages above ten, though in the aggregate urban population of the United States there is an excess of males between the ages of thirty and seventy, as well as below ten.

[5] Another difficulty in the way of the eradication project is that about one person in a thousand in almost every community is insane or idiotic, so that 0.1 per cent. may be taken as an irreducible minimum for illiteracy.

SELECTED STATISTICS OF AMERICAN EDUCATIONAL CENTERS, ETC., 1920

	Total population	Percentage of: Whites	Percentage of: Males	Percentage of: Adults	Persons per family: Total	Persons per family: Men	Persons per family: Women	Persons per family: Children	Children per woman	Percentages of: Adults illit.: Total	Percentages of: Adults illit.: Men	Percentages of: Adults illit.: Women	Percentages of: Families in "Who's Who"	Percentages of: Wage-earners
Whole United States		89.7	51.0	57.6	4.34	1.29	1.21	1.84	1.52	7.12	6.98	7.26	0.10	8.6
Urban population		93.2	50.1	62.4	4.24	1.34	1.32	1.58	1.20	5.50	5.14	5.87	?	14.3*
Rural population		86.0	51.9	52.4	4.45	1.23	1.10	2.12	1.92	9.15	9.19	9.10	?	4.4†
Washington, D. C.	437,571	74.6	46.5	69.8	4.55	1.45	1.72	1.38	0.80	3.34	2.99	3.63	1.62	7.0
New Haven, Conn.	162,537	97.1	49.3	60.5	4.48	1.33	1.37	1.78	1.29	8.10	7.17	8.99	0.58	19.0
Cambridge, Mass.	109,694	95.0	47.8	63.3	4.33	1.28	1.46	1.59	1.09	3.88	3.73	4.01	1.18	20.5
Berkeley, Calif.	56,036	96.7	46.9	67.6	3.70	1.14	1.36	1.19	0.88	1.23	1.41	1.12	1.09	4.1
Madison, Wis.	38,378	99.2	47.8	65.5	4.08	1.26	1.41	1.42	1.01	3.28	3.72	2.88	1.73	8.3
Evanston, Ill.	37,234	93.2	46.0	65.0	4.40	1.28	1.58	1.53	0.97	2.46	2.69	2.28	1.77	3.8
Poughkeepsie, N. Y.	35,000	97.5	47.7	64.6	4.02	1.22	1.38	1.42	1.03	4.56	4.58	4.52	0.39	16.9
Ann Arbor, Mich.	19,516	96.9	47.0	68.0	3.67	1.15	1.34	1.17	0.88	1.82	2.25	1.44	1.92	8.2
Ithaca, N. Y.	17,004	97.3	46.6	68.6	3.60	1.14	1.33	1.13	0.85	1.70	2.05	1.40	2.66	9.9
Lawrence, Kans.	12,456	82.3	46.5	64.0	3.58	1.05	1.26	1.28	1.02	1.83	1.70	1.92	1.30	4.0
Morgantown, W. Va.	12,127	97.7	49.5	58.6	4.12	1.19	1.22	1.71	1.40	1.40	1.51	1.28	0.78	10.7
Bloomington, Ind.	11,595	95.8	49.1	59.3	3.80	1.09	1.16	1.55	1.33	3.46	3.76	3.19	1.08	12.2
Iowa City, Iowa	11,267	99.2	45.5	67.7	3.69	1.11	1.39	1.19	0.86	1.01	0.65	1.30	1.77	2.9
Boulder, Colo.	11,006	98.8	45.8	64.5	3.70	1.05	1.33	1.32	0.98	0.34	0.38	0.30	0.70	1.5
Eugene, Oregon	10,593	99.8	47.2	65.0	3.54	1.08	1.23	1.23	1.01	0.52	0.40	0.63	0.33	5.0
Columbia, Mo.	10,392	81.5	46.9	63.9	3.64	1.07	1.26	1.32	1.04	5.62	5.71	5.55	1.89	2.7
Urbana, Ill.	10,224	96.7	47.1	63.8	3.88	1.14	1.35	1.40	1.05	1.32	1.50	1.16	3.68	5.0
Manhattan, Kans.	7,989	96.3	47.8	63.3	3.78	1.14	1.26	1.38	1.10	0.77	0.83	0.72	0.38	?
Ames, Iowa	6,270	99.3	48.5	65.0	3.66	1.14	1.24	1.28	1.03	0.49	0.56	0.42	1.28	?
Wellesley, Mass.	6,224	99.4	44.5	65.5	4.46	1.21	1.71	1.54	0.90	2.94	3.90	2.26	2.08	?
Princeton, N. J.	5,917	82.5	48.2	67.7	3.84	1.25	1.36	1.24	0.92	3.91	4.12	3.74	8.60	?
Palo Alto, Calif.	5,900	95.7	46.4	68.0	3.55	1.07	1.33	1.14	0.86	0.27	0.39	0.18	5.06	?
Amherst, Mass.	5,550	96.8	47.2	64.4	4.05	1.18	1.43	1.45	1.02	4.40	4.15	4.60	3.14	?
Fayetteville, Ark.	5,362	94.2	47.2	58.4	3.95	1.08	1.23	1.64	1.34	3.36	3.82	2.94	1.33	?
Norman, Okla.	5,004	99.7	47.5	58.5	4.18	1.16	1.29	1.73	1.35	0.92	1.01	0.85	0.92	?
Williamstown, Mass.	3,707	97.4	48.6	64.4	3.97	1.23	1.32	1.42	1.07	2.52	2.52	2.52	3.10	?
Average of 23	15,000	95.3	47.2	64.5	3.86	1.15	1.34	1.38	1.04	2.18	2.33	2.06	2.04	6.8‡

* Cities of over 10,000 inhabitants only. † Cities up to 10,000, as well as the country population. ‡ Average of 14.

ested would do well to make similar studies for such places as Fall River and New Bedford, Mass., Lackawanna, N. Y., Paterson, N. J., Dickson City and Old Forge, Pa., Hamtramck, Mich., Chicago (especially the wards bordering the Chicago River and drainage canal), Cicero and Herrin, Ill., and the home counties of legislators who have introduced anti-evolution bills in various state legislatures since 1922.[6]

Some persons might not see much advantage in living in a community with a large proportion of females, adults and noted persons, and small families and little illiteracy, if they thought they could do just as much, or more, business in some other kind of place. But good government and freedom from crime are certainly worth having, and the reader will probably have difficulty in recalling any news of political scandals, strikes or crimes from any typical college town. Or if crimes are committed, they may be the work of invaders from less civilized communities, as is often the case in Evanston, on account of its proximity to Chicago. Another point worth considering is that the average of feminine pulchritude is almost certainly higher in cultured communities than it is elsewhere, though it may be impossible to prove that statistically in the present state of our knowledge.

In spite of all this, strange to say, there are "boosters" in many educational centers who would like nothing better than to get some new railroads, stores or factories, to increase the quantity of population regardless of quality, and thus sacrifice the future for a little "unearned increment" of property values, or a temporary increase in business.

One slight drawback to living in a college town should be conceded, however. Rents and commodity prices are sometimes, perhaps usually, a little higher in such places than elsewhere, though this may be only a reflection of the high standard of living. Within 150 miles of New York there is a small college town with 64.4 per cent. of adults and 3.97 persons per family (in 1920), about six miles from a larger manufacturing center with 60.5 per cent. of adults and 4.44 persons per family. In the latter place 27.1 per cent. of the total population are wage-earners (more than one per family), and the average wages in 1919 were \$935 (as compared with \$1,075 in the whole state). Prices of some kinds of merchandise are lower in the factory town, and some college professors who have automobiles take advantage of that fact and go over there to buy their groceries.

[6] "Middletown," the subject of a recent much-discussed book by Robert S. and Helen M. Lynd, is easily identified with the aid of a few census volumes, and is almost the antithesis of a college town in some respects, although it is the seat of a state normal school and has remarkably small families.

THE CLIMATIC FACTOR IN MAN'S PHYSICAL ENVIRONMENT

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MAN'S climatic environment affects him in many ways. His clothing, dwellings, food, occupations and customs; his physical and mental characteristics; his system of government; his migrations; his history—all are affected to a greater or less degree. The atmosphere is as essentially unalterable as it is all-pervading. Montesquieu declared that the most enduring of all empires is the empire of climate. "Its dominion is invincible. Its laws must be obeyed. It makes no compromise and it grants no pardon." We may irrigate a portion of the earth's surface and thus remove it partially from the dominion of its local climate, but we maintain this change only by unending effort. If left to itself, the desert will encroach upon the irrigated area. Ancient cities which have been buried in the sands of the desert are evidences of the dominion of climate, rather than of the destruction accomplished by man. Man often thinks that he is conquering nature when he really merely discovers her laws and conforms to them. We have learned to adjust ourselves to some extent to our climates, but we can not change those climates.

It is natural that, even from the earlier days of classical writing, emphasis was laid upon the importance of climate in controlling man's activities, and especially in determining many of his characteristics. The ancients believed in direct and immediate effects of weather and climate upon disease. Similarly, they believed in direct effects of atmospheric conditions upon man's physical traits and upon his character.

Early views on climatic environment.[1] In his treatise "On Airs, Waters and Places," Hippocrates made what appears to have been the first serious attempt to correlate racial and social types with differences in physical environment. In comparing Europeans with the inhabitants of Asia, he says that

> the former are of great variety, vigor and fierceness, while the latter are known for their equable and gentle dispositions. These qualities are in agreement with the rapidly changing seasons of Europe on the one hand and the mildness and uniformity of the Asiatic climates on the other. To develop vigor and bravery, a climate is needed which will excite the mind, ruffle the temper and demand fortitude and exertion.

Europe, he believed, had a variety of people because it has a variety of climates, while Asia, where he considered the climate much more uniform, had uniformity of population.

Aristotle made an interesting point on the influence of climate on government. The people who live in the cold climate of northern Europe, he said, are conspicuous for their spirit, but their lack of intelligence makes them unsuitable for political organization. Asiatic peoples, on the other hand, have intelligence and inventiveness but lack spirit and are content to remain in subjection. The Greeks, intermediate in position, were held to combine the advantages of both extremes without their disadvantages, and were therefore, in Aristotle's opinion, the best-governed people and naturally fitted to rule the earth.

In his "History of Rome," the Greek historian Polybius, with keen insight, suggested the possibility of overcoming the detrimental influences of climate

[1] In the following paragraphs on the views of the ancients, the writer has drawn very freely on Professor Franklin Thomas's "The Environmental Basis of Society," New York and London. The Century Company. 1925.

upon national character by education and discipline. He gave as follows the reasons for the introduction of music into Arcadia:

> They saw that Arcadia was a nation of workers; that the life of the people was laborious and hard; that as a natural consequence of coldness and gloom, which were the prevailing factors of a great part of the country, the general character of the people was austere . . . and it was with a view of softening and tempering this natural ruggedness and rusticity that they introduced the things which I have mentioned.

The most extensive discussion by a Roman author of the influences of climate upon the mental and physical characteristics of a people is found, curiously enough, in the work of a writer on architecture, Vitruvius. The men of the north, he says, "are helpless in the face of fevers or great heat, but are brave in war because of their large supply of blood." Men of the far south living under the direct rays of the sun "have too much moisture drawn out of their systems and hence have little blood." They can easily endure fever and heat, but are timid in battle. They are of lower stature than northern peoples; have a swarthy complexion, curly hair, black eyes, strong legs and little blood. Southern peoples have a keen intelligence because of the rarity of their atmosphere and the heat. Northern peoples who live in a dense atmosphere are "chilled by moisture from the surrounding air, and have but a sluggish intelligence." He illustrates this point by calling attention to the activity of snakes in warm weather as contrasted with their torpor in cold weather. People who live in cold countries are physically better equipped for fighting, but their courage is not intelligent and they are likely to lose through their lack of judgment. The conditions which produce the best races are intermediate between these extremes, and Vitruvius uses as his illustration the region occupied by the Romans. It will be observed that Aristotle thought that the superior people were located a little farther south, namely, in Greece. The "line of racial superiority" was thus moved in accordance with the nationality of the writer.

Pliny wrote:

> There can be no doubt that the Ethiopians are scorched by their vicinity to the sun's heat, and they are born, like persons who have been burned, with the beard and hair frizzled; while, in the opposite and frozen parts of the earth, there are nations with white skins and long light hair. The latter are savage from the inclemency of the climate, while the former are dull from its variableness. . . . In the middle of the earth there is a salutary mixture of the two, a tract fruitful in all things, the habits of the body holding a mean between the two, with a proper tempering of colors; the manners of the people are gentle, the intellect clear, the genius fertile and capable of comprehending every part of nature. They have formed empires, which has never been done by the remote nations, yet these latter have never been subjected by the former, being severed from them and remaining solitary, from the effect produced on them by their savage nature.

"The middle of the earth" doubtless referred to Rome.

Galen, the great medical writer, believed that "a cold climate would aid the progress of a disease caused by cooling of the elements, and prevent one caused by heating of the elements." The same ideas were held to apply to hot, dry and wet climates. In general, Galen followed the theories of Hippocrates.

These extracts must suffice to indicate the general trend of thought among ancient writers in regard to the direct effects of climate upon man. Mention of a considerable group of the medieval writers must be omitted for lack of time, and we must pass at once to Montesquieu (1689–1755). In "The Spirit of Laws" there are numerous interesting references to the importance of the climatic factor in man's environment. Montesquieu held that the people in cold countries "tend to be brave, vigorous, insensible to pain, and are possessed of strong physique and of phlegmatic tem-

peraments." On the other hand, those who live in warm climates "are weak, timid, opposed to physical exertion, vivacious, sensitive to pleasure or pain, and are lacking in mental ambition." If the climate makes people stubborn, the laws are tyrannical. On the other hand, if the climate makes them gentle, the laws are liberal. Political conditions, Montesquieu believed, are also markedly influenced by climate. Northern peoples, stronger and more vigorous than those of the south, are easy conquerors in warfare. Therefore, where a warm country adjoins a colder one, the former will be conquered and ruled by the latter.

Intemperance, in Montesquieu's view, increases with the cold and dampness of the climate and with distance from the equator. In hot countries the loss of moisture through perspiration must be offset by drinking a great deal of water; in cold climates, on the other hand, spirituous liquors are necessary in order to prevent the blood from congealing. Montesquieu also maintained that climate has a decided influence on domestic and conjugal relations. In warm countries women mature earlier; they are less wise than their husbands and are naturally inferior in status. By reason of this fact, together with the low cost of living and an excess of females in warm countries, polygamy is common there, while monogamy prevails in cold countries. This condition prevented the progress of Mohammedanism in cool countries and of Christianity in warm latitudes.

Buffon held that man was originally of one type and changed because of the effects of environment. Hence, if a negro were to return to a temperate climate he would in a few generations become white again. Herder wrote: "We are ductile clay in the hand of climate," and believed that, while climate can not change the species, it can cause variations within the species which are transmissible through heredity. Von Humboldt held to the view, which was advanced long before his time, that the temperate zone is best suited to man's intellectual development and to his control over the forces of nature. Adam Ferguson, in his "History of Civil Society," maintained that in cold climates people "are dull and slow, moderate in their desires, regular and pacific in their manner of life," while in warm climates they are "feverish in their passions, weak in their judgments and addicted by temperament to animal pleasures."

Some modern views regarding climatic environment. Among modern writers Friedrich Ratzel, whose work has become well known to English and American readers through the writings of Miss Ellen C. Semple, has given the most thorough discussion on environmental influence. He believes that climate affects man directly through its influence on his physical and mental characteristics and indirectly through its effect upon his animal and vegetable food. In common with Aristotle, Ratzel maintains that temperate zone peoples are superior both from a political and military point of view. They are also more advanced in culture than the polar and equatorial zone people. In the temperate zones themselves, the people who live in the colder portions are superior to those who live in latitudes nearer the equator. He also holds that differences of climate in neighboring districts may be disadvantageous because they make political union more difficult. A general similarity of climate is conducive to economic uniformity and political unity. Buckle, in his "History of Civilization in England," stresses the effect of physical environment upon the human race. Climate, soil and food together determine the accumulation of wealth, and the accumulation of wealth must precede any high development of knowledge. There can, according to Buckle, be no leisure without wealth and no knowl-

edge without leisure. In the early stages of the accumulation of wealth, energy and the regularity of labor depend upon climate, and the returns of labor depend upon the fertility of the soil.

Guyot, in a passage which has become a classic in the literature of anthropogeography, wrote as follows:

> Since man is made to acquire the full possession and mastery of his faculties by toil, and by the exercise of all his energies, no climate could so well minister to his progress in this work as the climate of the temperate continents. It is easy to understand this. An excessive heat enfeebles man; it invites to repose and inaction. In the tropical regions the power of life in nature is carried to the highest degree; thus with the tropical man, the life of the body overmasters that of the soul; the physical instincts of our nature those of the higher faculties; passion, sentiment, imagination, predominate over intellect and reason; the passive faculties over the active faculties. . . . In the temperate climates all is activity, movement. The alternations of heat and cold, the changes of the seasons, a fresher and more bracing air, incite man to a constant struggle, to forethought, to the vigorous employment of all his faculties. . . . Thus, if the tropical continents have the wealth of nature, the temperate continents are the most perfectly organized for the development of man. They are opposed to each other, as the body and soul, as the inferior races and the superior races, as savage man and civilized man, as nature and history.

Dr. Ellsworth Huntington has written several volumes as well as a large number of shorter articles on climatic influences on man. He has studied the relations of various conditions of climate and weather to human efficiency and has determined what are the best climates for the maximum mental and physical activity. On the basis of these and other studies he has correlated the distribution of civilization and of climate and found a close coincidence between the highest civilization and the most favorable climate. Huntington believes that climate is the chief factor in determining health conditions and human activity; that as climates have fluctuated or varied in past times, nations and peoples have had epochs of great success and prosperity or have decayed; they were at peaks of prosperity and power when their climate was at its optimum; they declined when their climate was depressing. The number of factors concerned in such great epochs is so large, climate being only one of them, and the historical, biological and physiological reactions are so important, that some of the more conservative climatologists hesitate to follow Dr. Huntington to all the conclusions which he has reached.

Weakness of old views regarding effects of climate on man. It is easy to go too far in calling upon climate to explain phenomena which we may otherwise find it difficult to account for. This was the mistake formerly made by most of the writers on this subject. Thus Gervase of Tilbury, in the thirteenth century, said that "according to the diversity of the air the Romans are grave, the Greeks fickle and unreliable, the Africans sly and crafty, the Gauls fierce and the English and Teutons powerful and robust." The same writer held that the violent mistral blowing in the Rhône Valley generates in this region men who are windy, empty-headed, inconsistent and untrustworthy. Another writer of the middle ages, Otto of Freising, suggested that the Lombards who settled in Italy lost their ferocity largely on account of marrying Italian women, but also partly because of the nature of the country and the climate. Maupertuis and others held that the color of man's skin becomes paler with increasing distance from the equator. Livingstone wrote that in Africa religious ideas seemed to depend upon distance from the equator. One writer held that cold produces a small stature; another believed that the pygmies are small because of the heavy seasonal rains which fall in hot equatorial Africa. Climate was believed to explain the overhanging eyebrows and partly closed eyes of the Negro, the small eyes and beardless faces of the Chinese, the supposed fact

that more twins were born in Egypt than elsewhere, and so on. The broad generalizations of Montesquieu, Voltaire, Buffon, Hume, Buckle and others furnish interesting reading and contain much that is suggestive and instructive, but they usually carry us well beyond the range of reasonable probability.

In looking through the extensive literature on the influence of environment, it is perfectly clear that the dominant view of the earlier writers, even down to the time of Buckle, was that environment acts directly and immediately upon the individual, not only upon his physical characteristics but also upon his mental traits and his character. Montesquieu, for example, as we have seen, held that a direct correlation exists between climate and mental traits. Finding themselves face to face with many puzzling facts, difficult of explanation, the ancient writers, as so often happened in the early days of science, seized upon one general blanket theory—the influence of climate—and attributed to that one cause the highly complex series of facts which they could not otherwise clear up. While such broad views have now generally been rejected, several more recent writers hold that weather conditions temporarily affect the habits and characteristics of individuals, and therefore react upon the characteristics of the group as a whole.

In his very significant essay, "The Pacific Coast: a Psychological Study of the Relations of Climate and Civilization," the late Professor Josiah Royce, of Harvard, clearly expressed his views on this matter as follows:

> The outer aspect of nature unquestionably molds both the emotions and customs of mankind, insensibly affects men's temperaments in ways which, as we know, somehow or other tend to become hereditary, however we may view the vexed question concerning the heredity of acquired characters. . . . The tendencies of the moment are in their way indications of what the tendencies of the ages are to be. . . . In the case of such a climate as the one of California, your relations with nature are essentially intimate, whether a student of nature or not. . . . This intimacy with nature means a certain change in your relations to your fellow men. You get a sense of power from these wide views, a habit of personal independence from the contemplation of a world that the eye seems to own. . . . The California proprietor can have, during the drought, more leisure unless, indeed, his ambition for wealth too much engrosses him. . . . In California the more regular routine of wet and dry seasons modifies and renders more stable the general psychological consequences. All this is encouraging to a kind of harmonious individuality that already tends in the best instances toward a somewhat Hellenic type. . . . In California, unless you are afraid of the rain, nature welcomes you at almost any time. The union of the man and the visible universe is free; is entirely unchecked by any hostility on the part of nature, and is such as easily fills one's mind with a wealth of warm experience . . . not the relation of hostility but of closeness. And this is the sort of closeness determined not merely by mild weather, but by long drought and by the relative steadiness of all the climatic conditions. . . . Individuality, then, but of a peculiar type, and a tendency despite all this individualism toward agricultural conservatism and a definite social organization—these are already the results of the climate.

A recent writer has said, "The modification of animals and of plants under direct or indirect climatic controls naturally prejudices us in favor of the belief in similar modifications in man himself. There is, however, little reliable evidence in favor of such a view, however strong the probability may appear to be. We are nowadays somewhat skeptical about attributing to climate immediate and direct effects upon the mental and physical characteristics of man, individually and racially." Professor Franklin Thomas writes: "Modern social scientists, as a rule, are coming to regard geographic factors more as conditioning influences than as determinants, and to hold that man and culture, primarily, are the dynamic and determining factors." Or, as another has expressed it, "The environment furnishes the builders of cultural structures with brick and mortar but it does not furnish the architect's plan." What-

ever weight may be given to climate alone, as distinguished from the influence of the physical and the psychical environment, it is certain that climate must always be a factor. "The physical environment always includes climate."

Into the controversy as to the relative weight to be attached to climate on the one hand and the psychical element on the other I have no desire to enter. There are three general types of view in this matter. The first holds that environment is all-controlling; the second, that environment counts for little because the psychical element dominates mankind after the primitive ages are past; the third, that environment is an important factor to which a varying degree of influence is always to be ascribed. It seems to me that we may best illustrate the situation by means of a very simple formula, E + x, in which E is the environment, including climate, and x is man, *i.e.*, the psychical element. The controversy centers about the relative sizes of E and of x. Those who give increased weight to the environment naturally write the E large, and those who consider the psychical element more important increase the size of the x. Obviously the problem is a very difficult one because so many factors are involved in it. No simple and satisfactory solution is possible because the present state of science will not permit us to attempt any definition or any measure of the influence of climate upon the human race and its accomplishments or upon individual man. A great deal has been written as to the dominant influence of climate which is highly unsound and exaggerated beyond all bounds of reason. On the other hand, it is equally true that climatic influences are all-pervasive. It is the general view of the more recent writers that the environment has its maximum influence in the case of primitive man, and that, with the advance of civilization, the part played by the psychological and cultural factors becomes increasingly important. The more intelligent and the more highly civilized man becomes, the less he is at the mercy of his climate and the more he contrives to protect himself against it and to avoid the unfavorable elements in it. Man thus learns to adjust himself to his climate. He accomplishes what has been termed a "conditional conquest." He can not change his atmospheric surroundings, certainly not in any large way. He can never really "master his climate." He can tolerate it, he can not be independent of it. His habits are largely controlled by it. Hence it is true that "men seldom change their climate because to do so they must change their habits."

The more complex the development of human society; the more the different parts of the world are linked together; the more dependent nations become upon food supplies from other countries, the more direct and far-reaching the effects of weather and of climate inevitably must be. A disastrous drought involving a partial failure of the wheat crop in Argentina or in Canada reacts unfavorably upon the British Isles. A reduction of the cotton crop in the United States by frost affects the world's markets. A flood in China, accompanied by great loss of life, diminishes the demand for imported goods there. A serious deficiency of rainfall in Australia and lack of pasturage for cattle increases the price of beef and mutton exported from there to other countries.

Factors in the problem other than climate. To most of the older writers climate meant more than it does to-day. It included much of what is now termed our whole physical environment. Moreover, they based their conclusions upon incomplete records covering far too short periods of time. It must be remembered that we are dealing here with large, important, highly complex phenomena. Man moves readily from place to place, from climate to climate. His food,

drink, habits, occupations, to some extent his physical and mental characteristics, change in consequence. Inheritance, intermarriage, environment, opportunities, soil and many other factors enter in to determine what changes individual man and the race as a whole shall undergo. Time is a very important element in the final result, for in time a gradual adaptation to new conditions takes place. Climate is but one of many controls, albeit a most important one, for it largely determines what many of the other factors, such as diet, customs and occupations, for example, shall be. The task of giving climate its proper place as a factor controlling the life of man as a whole is a difficult one which can not be definitely and satisfactorily solved today, or to-morrow.

Climate and habitability. Climate determines both how and where man shall live. It classifies the earth's surface for us into the so-called habitable and uninhabitable regions. The desert of sand and the desert of snow and ice, whether the latter be near sea-level or high up on mountain tops, are alike climatic: the former because of aridity; the latter because of cold. The only non-climatic deserts are recent lava flows. Where a soil is present which is not frozen for much over half the year and where there is reasonable temperature and sufficient rainfall, plants and animals are found, ranging from few and lowly forms where conditions are the hardest and where all organic life is especially adapted to these conditions, to the greatest abundance where conditions are most favorable.

Man is influenced by much the same controls as those which affect plants and the lower animals. From the highest latitudes he is excluded by cold. The high altitudes are hostile both because of cold and because of diminished pressure. The deserts of sand are all thinly populated by reason of aridity. Forests, where rainfall is abundant, are unfavorable to a dense population. The trees must be cleared away before settlement is easy. Man is widely distributed over the earth's surface. In his migrations he has carried with him, beyond their original limits, many plants and animals. But the life of man is harder here and easier there according to climatic conditions and the scarcity or abundance of plant and animal life.

Man is distributed in great belts around the world corresponding roughly to the broad zones of vegetation, desert, steppe and forest, the limits of which are set by temperature and rainfall. But man is much more dependent on rainfall than upon temperature. Water he must have, either directly from the clouds or indirectly from rivers, springs or wells, or from melted snow and ice. There are certain common conditions of life which affect the people who live in the same zone in the same broad, general way, just as these zones have similar general conditions of winds and rainfall. This, Ratzel has pointed out, means that there is a climatic factor at work to maintain differences between the people of different zones in spite of the great movements which are constantly tending to produce uniformity. Obviously, the differences in the life of man which depend upon climate will be most noticeable and will be likely to have the greatest historical significance when marked contrasts of climate are found close together, as in the case of mountain ranges like the Alps, or of a pronounced lowland, plateau and mountain topography like that of Peru or Mexico. All the regions of sparse population are gradually being encroached upon by invasion from their borders. Forests are being cleared and replaced by open agricultural lands. Wheat and corn are replacing grass in the steppes and savannas where irrigation can be practiced. Deserts are being reclaimed for farming here and there where water is available, and the more civilized man becomes, the

denser the population which the different parts of the earth can be made to support. It is the story of a more complete to a less complete mastery of man by his environment, but in spite of all that man can do, the large climatic limitations persist. The Greenland desert of snow and ice and the Sahara desert of sand must remain practically deserted.

Australia, Madagascar and South Africa have the bulk of their population on the east, where the rainfall is most abundant. To the westward, there is a rapid decrease both in rainfall and in population. In the interior of the United States, the population diminishes rapidly to the westward of the one hundredth meridian, where the critical rainfall boundary of twenty inches is reached. The distribution of population along the Pacific coasts of the two Americas is a direct response to the rainfall or to irrigation. Europe is favored in having but limited areas which suffer from deficient rainfall. The interior and southeast of the Spanish peninsula and the steppes of eastern Russia have a restricted population because of the deficiency of rainfall. Russia's population "leans westward," as Professor Mark Jefferson has expressed it, towards the heavier rainfall, but the population of the Iberian Peninsula is marginal in agreement with the distribution of its rainfall. Australia is largely a trade wind desert; the eastern border has the most favorable rainfall, and it is there that the present and the future population must chiefly settle. Over most of the United States west of the one hundredth meridian, except in irrigated districts and on the Pacific Coast, and in the interior and western parts of Asia, the population will always be thin. There is not enough water in either of these great areas for any considerable increase in irrigation. Extreme cold and aridity prevent the cultivation of the soil in the far north and therefore inevitably limit the population and prevent or retard economic and social development.

If we look about the world to-day we find that the general state of civilization is markedly influenced by precipitation. Temperature also plays a very large part in determining the growth of natural vegetation and of crops, but the most obvious control—the one that is most striking in a climatic survey—is rainfall. In wet forests we find hunters who live an uncertain and impoverished existence. Deserts and dry steppes produce nomads who give up their lives to fighting and robbery. In intermediate climates farming is the dominant occupation; the people are peaceful and eventually develop stable governments. When arid lands are irrigated the nomadic population is replaced by a sedentary people, occupied in agricultural pursuits. It is in such regions that the origin of civilization is to be sought.

Primitive civilization and the tropics. It has been generally thought that man in his earliest stages, when most helpless, was an inhabitant of the tropics; that he lived in the mild, uniform, genial climate of that zone where food was easily obtained and protection against the inclemencies of the weather least necessary.

The recent investigations in the deserts of Central Asia have been turning many people's thoughts in that direction as the region of man's very early habitation. In the far distant past, on the border-zone between the last Ice Age and what we may call, in a rather loose way, historical times, Central Asia seems to have been a land of sufficient rainfall while most of northern Europe and of North America was ice-covered. Glacial periods were times of more precipitation, as well as of somewhat lower temperatures. With the change to climates essentially like those of to-day, there was a change to less rainfall, as well as to a slightly higher temperature. This

transition was a gradual one, probably with oscillations extending over long intervals of time.

The earliest civilizations seem to have developed in arid climates or on their margins—in the ancient Orient, Mesopotamia, parts of India, the interior of China and Egypt. In the western hemisphere, the Peruvian, Mexican and Pueblo cultures were developed under fairly similar conditions. The conditions for the development of these civilizations were found in irrigation, which insures abundant and regular crops as long as man leads a well-organized community life and does not relax his labors. In these irrigated localities lived races more energetic and more hardy than those of the damper and rainier portions of the tropics where vegetation was more luxuriant. Civilization was probably first developed, not where the overwhelming superabundance of nature's gifts seems to offer the best conditions, but where man was under some stress of labor, some spur to effort, in less favorable natural conditions, but such as developed him.

The nations living at ease on the tropical lowlands were naturally, from early days, the object of frequent attacks and invasions at the hands of the more active and more warlike races living in more rigorous climates farther north, or at greater altitudes on mountains or plateaus. The invading tribes, having in time become enervated by an easy existence on the warm lowlands, were themselves often later overcome by new enemies from the north. Some of the greatest migratory movements in history have taken place from colder to warmer climates, as part of this general equatorward tendency in both temperate and tropical zones. The barbarous tribes broke through the northern passes and descended onto the more genial and more fruitful lowlands of India, being helped to do this by the ease of the descent. Such mountain systems as the Himalayas, or the Alps, stretching east and west, are natural climatic divides between more genial and more severe climates, and have often been crossed by invading armies from the north. The descent of the Aryans into India, the Manchurian conquest of China, the invasion of Greece and Italy from the north, the southward movement of Toltecs and Aztecs in Mexico—all have been cited as illustrations of this equatorward tendency. Sir Flinders Petrie in his "The Revolutions of Civilizations," has said:

> There is no advancing without strife. Man must strive with nature or with man, if he is not to fall back and degenerate. The harder and longer a nation strives the more capable it will be. This is not only the slow result of selection, but it is the immediate result in each individual produced by the attitude of his mind. The northern nations, accustomed to striving against climate, thrive vastly when they get into easier countries until their tone is let down to their conditions.

Geographical march of history. A gradual migration of the center of civilization away from the tropics and the highest development of the human race not where life is easiest but in extra-tropical latitudes are significant. Herbert Spencer clearly stated his view that the geographical march of history has been a steady progression from the warmer and more productive regions necessary in the feebler stages of social evolution to the colder, less productive and more difficult regions away from the tropics. He wrote as follows:

> I do not ignore the fact that in recent times societies have evolved most, both in size and complexity, in temperate regions. I simply join with this fact that the first considerable societies arose, and the primary stages of social development were reached, in hot climates. The truth would seem to be that the earlier phases of progress had to be passed through where the resistance offered by inorganic conditions was least; and when the arts of life had been advanced, it became possible for societies to develop in regions where the resistance was greater; and that further developments in the arts of life, with the further discipline in co-

operation accompanying them, enabled subsequent societies to develop, to take root and grow in regions which, by climatic and other conditions, offered relatively great resistances.

The focus of culture shifted from the ancient Orient to Greece, and Greece was succeeded by Rome. From the Mediterranean region, therefore, where the world's civilization, its commerce and its power were long centered, westward through Spain and Portugal, the migration continued farther and farther north until Holland and then England became the dominant power. From lands of more genial climates, rich in natural products, to lands of colder and longer winters, the migration has taken place. The advance of Christianity, from its origin in the subtropical belt of Eurasia into higher latitudes, has been pointed to as another illustration of the same tendency. Together with this northward tendency of civilization there has run through the past an equatorward movement, already noted in the case of the tropics, of the stronger peoples of the north toward the milder and more genial southern latitudes, involving historical events of great importance.

As Guyot summarized the geographical march of history and of civilization:

The man of the Old World sets out upon his way. Leaving the highlands of Asia, he descends from station to station towards Europe. Each of his steps is marked by a new civilization superior to the preceding, by a greater power of development. Arrived at the Atlantic, he pauses on the shore of this unknown ocean, the bounds of which he knows not, and returns upon his footprints for an instant. Under the influence of the soil of Europe, so richly organized, he works out slowly the numerous germs wherewith he is endowed. After this long and teeming repose, his faculties are reawakened; he is reanimated. At the close of the fifteenth century, an unaccustomed movement agitates and vexes him from one end of the continent to the other. He has tilled the impoverished soil, and yet the number of his offspring increases. He turns his look at once toward the east and the west, and sets out in search of new countries. His horizon enlarges; his activity preys upon him; he breaks his bounds . . . he abandons himself to the winds and the currents, which bear him gently towards the coast of America. He is enraptured as he treads the shore of this land of wonders, still more adorned in his eyes by all the fascinations his ardent imagination lends it.

Köppen makes the interesting suggestion that in the future there will be a gradual return to the irrigated regions of the subtropics where agriculture can be carried on under more favorable conditions. Thus, in his words,

The development which has led mankind from Babylon to London has in certain respects probably gone too far. On the one hand, it may be observed that too exclusive a concentration upon industry and trade in any country carries with it great changes, and, on the other, with the aid of modern science and technical skill, we are again going to practice agriculture under irrigation in conditions of uncertain rainfall. Thus the warm and sunny lands will regain some of the advantages which they have lost to the colder and damper climates, precisely in proportion to the degree with which man's scientific and technical skill succeeds in overcoming the difficulties of transportation and in mastering tropical diseases.

In his "Manual of Meteorology," Sir Napier Shaw has clearly stated his view in regard to the movement of civilization from its ancient centers to northern and apparently much less favorable climates. He writes,

According to the teaching of the new anthropology, human civilization was autochthonous in ancient Egypt, and spread from there over the world with subsequent subcenters of diffusion in Babylon and India. This view may not be accepted, but it arrests attention by the circumstance that Egypt, and especially the Egypt of the early Egyptians, is that part of the world which is most nearly independent of what we understand by weather. It draws its water supplies from the river and takes nothing but dew from the sky. It has winds generally so arranged as to temper and mollify the burning effect of the sun's heat, seldom strong enough to raise a dust-storm, and practically free from the terrible visitation known as simoom. At the same time it is wonderfully fertile with very little effort on the part of the husbandman. If then our civilization began in Egypt, we are faced with the conclusion that primitive man found the line of least resistance to his advance towards civilization in a country which has no weather, and yet enjoys a plentiful supply of water, with a sky so serene and genial as to make

clothing a matter of little importance and the indispensable shelter . . . an easy artifice. . . . Although the localities of genial climate, plenty of water and no weather are the easiest for human beings to live together in, they are apparently not the best in the long run. The civilizations that spread out from the original centers, carrying with them the contrivances for their own protection and enrichment that had been invented in the favorable locality, developed faster when they faced the vagaries of a weather-climate. Though we may trace the dawn of civilization to the country where cyclonic depressions are practically unknown, we must look upon the region of the maximum number of cyclonic depressions as the most favorable for the development of human energy.

Climate and man in the temperate zone. Intermediate in location, in mean temperature and in their physiological effects, the temperate zones, whatever was the condition in the past, are to-day clearly the center of the world's civilization, as they have also been the scenes of the most important historical developments for several centuries. From the temperate zones have come the explorers and adventurers of the past and are coming the exploiters and colonizers of to-day. In the occurrence of the temperate zone seasons lies much of the secret—who can say how much of it?—of the energy, ambition, self-reliance, industry, thrift, of the inhabitant of that zone. Guyot did not exaggerate when he wrote:

In the temperate zones all is activity, movement. The alternations of heat and cold, the changes of the seasons, a fresher and more bracing air incite man to a constant struggle, to forethought, to the vigorous employment of all his faculties. A more economical nature yields nothing except to the sweat of his brow; every gift on her part is a recompense for effort on his. . . . Invited to labor by everything around him, he soon finds, in the exercise of all his faculties, at once progress and well-being.

The monotonous heat of the tropics and the continued cold of the polar zones are both depressing. Their tendency is to operate against man's highest development. The seasonal changes of the temperate zones stimulate man to activity. They develop him physically and mentally. A cold, stormy winter necessitates forethought in the preparation of clothing, food and shelter during the summer. Carefully planned, steady, hard labor is the price of living in these zones. Development must result from such conditions. In the warm moist tropics life is too easy. In the cold polar zones it is too hard. Temperate zone man can bring in what he desires of polar and tropical products, and himself raises what he needs in the great variety of climates of the intermediate latitudes. Near the poles the growing season is too short. In the moist tropics it is so long that there is little inducement to labor at any special time. The regularity and the need of outdoor work during a part of the year are important factors in the development of man in the temperate zones. Where work is a universal necessity, labor becomes dignified, well-paid, intelligent, independent.

Behind our civilization there lies what has been well called a "climatic discipline"—the discipline of a cool season which refreshes and stimulates, both physically and mentally, and prevents the deadening effect of continued heat. On the other hand, a very long winter is about as unfavorable as a very long summer. If outdoor work is seriously interrupted, progress is retarded. Buckle based certain too broad generalizations on this consideration, and saw in it an explanation of similar national characteristics among peoples whose outdoor work is interrupted for the same length of time. But it is clear that the length of the farming season is a large factor in controlling the return from the soil, the kind of work done and the manner of doing it. It is not surprising to learn that the difficulty of keeping farm laborers through the long winter has been a handicap in western Canada, and that it was urged against the abolition of slaves in Russia that it would be im-

possible, without some form of compulsion, to keep farm-hands during the winter. A recent writer has pointed out that the winter climate of Canada has been perhaps the most favorable asset that that country can have. The severity of the climate, except on a small part of the Pacific coast, has eliminated the Negro question, which, he says, "weighs like a troublesome nightmare upon the civilization of the United States, which shadows the future of South America and gives many anxieties to Australia." This cold has also kept away the peoples of southern Europe who do not readily assimilate with the Anglo-Saxon stock, and has attracted the hardier immigrants from northern Europe.

The available evidence, both theoretical and as based upon history and human experience, indicates that man makes his best progress where he is forced by natural conditions of seasonal change to take thought for to-morrow, provided he also has time for the development of ideas. Agriculture, with the settled life which that occupation involves, usually provides such favorable conditions. Man must study the seasons. He must take thought for the future. He must, as population increases, widen the area under culture. He may have to irrigate. He becomes a thinking, planning and inventive creature. He develops his body and his mind. No writer has expressed more vigorously or more picturesquely the development of man and his conquests of the earth than has Dr. David Starr Jordan in the following striking lines:

> The strong races were born of hard times; they have fought for all they have had, and the strength of those they have conquered has entered into their wills. They have been selected by competition and sifted by the elements. They have risen through struggle, and they have gained through mutual help, and by the power of the human will they have made the earth their own.

Present-day migrations within the temperate zone. Within the north temperate zone especially, and also across from the north to the south temperate, vast, peaceful migrations are taking place, determined to a considerable degree by climatic considerations. From Europe and Asia to the United States alone, millions of people have migrated, and they are still coming. These immigrants have shown marked tendencies to settle where climate, soil and occupations are most like those of their old homes, although the fact that most of them land at one or two ports on the eastern seaboard, the concentration of industry in certain sections and other controls have operated very effectively to counteract and interfere with this tendency. Scandinavians, for example, have gone largely into the northwest; in the future the southern parts of the United States will probably have a much larger Latin population, who will there find homes and occupations in climates best suited to their needs. It is an undoubted fact that the large colored population in the south, the result of the importation of slave labor to do work which the whites found themselves unable or unwilling to do, has been an important factor in checking the movement of recent European immigrants into the southern states. This is one reason why the white population of the south is still so essentially Anglo-Saxon and homogeneous, while the north has become a great complex of diverse nationalities and tongues. Canada has grown slowly, partly on account of the repelling effect of her long, cold winters and her generally severe climate. Of late years, however, the rapid settlement of farming lands in the United States, the attraction of free, or cheap, lands in western Canada and the success which has been attained in raising wheat and other crops during the short but favorable Canadian summer have combined to induce a considerably increased immigration of farmers from the United States and of north Europeans into

Canada. Present-day migrations within the temperate zone are peopling Canada, South Africa and Australia with the same stock that occupies the homeland of the British Isles. Therefore institutions and government essentially similar to those at home are possible in these lands. The case is very different in tropical climates.

In Argentina, the climatic control of migrations is even more clearly marked than in the United States, the Italians tending to settle towards the north, where the climate is most like their own, while the races from northern Europe show a tendency towards the south. Many Italians take advantge of the differences in seasons in the northern and southern hemispheres and do two seasons of summer work each year, one on each side of the equator. It is interesting to observe how immediately controlled by the special weather conditions of even one season these voluntary migrations may be. Years of sufficient rainfall and abundant crops in the United States were usually followed by a larger immigration, that is, before the present policy of limited immigration was established. A failure of crops in Europe, whether of wheat in one country or of fruit in another or of potatoes in another, resulting from drought or storms or excessive rainfall, is always likely to promote a larger exodus from the country concerned. There is, furthermore, a considerable seasonal migration across the Atlantic. Many Italians have come to the United States in the spring to work during the warmer months, when farm and outdoor laborers are in demand, and have returned to the milder climate of Italy for the winter.

The continents and the temperate zone. Europe is well situated climatically, being almost altogether in the temperate zone and open to the ocean on the west, so that nearly all parts of it are well watered. Asia is an overgrown country. Much of it is in the temperate zone, it is true, but the interior is so far from the sea that the climate is severe and the rainfall very deficient. This condition of hopeless aridity is depressing in the extreme, and this region is prevented from becoming thickly populated or important on that account. Most of Africa is within the tropics. Its plateaus will furnish considerable areas not wholly unfavorable for white settlement. The southern part of Africa is just within the marginal subtropical belt of the south temperate zone. The same is true of Australia. South America is widest within the tropics. Its west coast is peculiar in having the tempering influence of high plateaus in the interior and of a cool ocean current along the coast. Its southern portion tapers off into the south temperate zone. The narrowing of Africa and of South America toward the south results in providing a comparatively limited area of well-watered plains for future settlement. North America is widest in the temperate zone, and this is one of its greatest assets. It suffers from the extreme cold of its winters in the north and from the rain-shadow effect of its western mountains, which gives the interior basin and part of the western plains a deficient precipitation.

Differences between northerners and southerners. There are certain broad, distinguishing characteristics of man in the temperate and tropical zones, in determining which it is reasonable to believe that climate has played a part. Similarly, there has been a natural tendency to attribute certain differences between northerners and southerners in the temperate zones themselves to a difference in climate. The former, living in a duller, harsher climate, with long dreary winters, are more serious, more industrious, more enterprising and act after more mature deliberation than the latter who, reflecting their brighter skies, are more cheerful, more kindly, more impulsive, more genial, more gen-

erous and also less energetic and more easy-going. The northerner must exercise more forethought, care, industry and prudence; he has to work harder and is usually better paid than the southerner. These national differences are proverbial between northern and southern Germans, French, Spanish, Russians, Italians, Arabs and other peoples. The influence of climate has likewise been traced in the sad, even pessimistic tone of much of the northern literature, and in the gravity and melancholy of modern northern music as well as of the northern folk-songs. Mr. John Masefield has written a very suggestive comment on English poetry.

Because poetry is an art of the sun and because poets are inspired according to their degree of light, I can not declare that our English poets are the best the world has ever known. We have not a terrible climate . . . therefore our art is not terrible. Neither have we the bleakness of Spain which produces a severe art, nor the gentle climate of Italy which makes the art of Italy so gracious, and we have not the clear climate of France, which makes the art of France just. . . . We have a temperate climate, and therefore a temperate art. Our poets are not likely to go to either extreme.

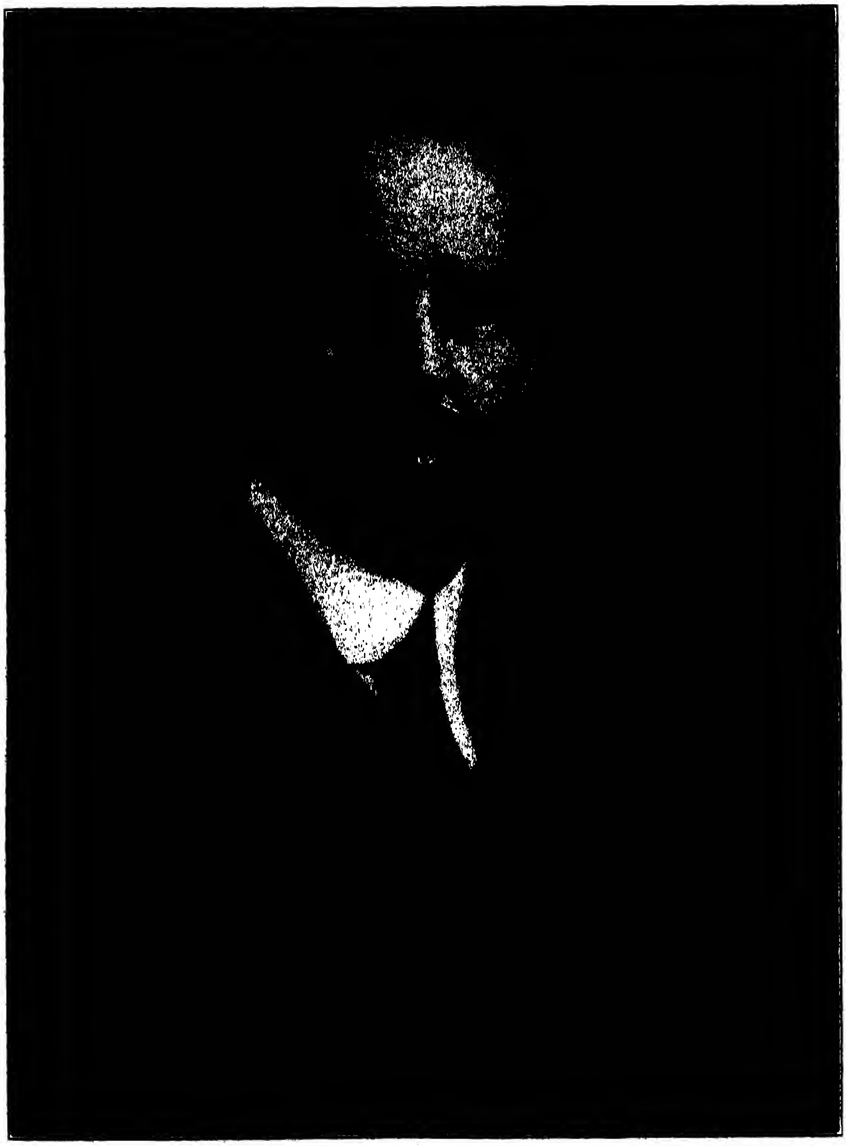
In regard to the sadness and melancholy of the Russian peasant, a Russian writer has said:

During the long winter months when the climate is most rigorous, a large part of the Russian population is undernourished. In the autumn it rains for weeks in succession. The steppes are gray and monotonous. Dismal forests stretch over hundreds of miles. All these conditions communicate themselves to the underfed brain, which imperceptibly passes over into a brooding melancholy that crushes the individual like a nightmare, filling him with dead inertia and hopeless resignation.

Sir Archibald Geikie, in his "Scottish Reminiscences," has emphasized the climatic influence in producing the grim character of the Scot in the following words:

The gloom of his valleys is deepened by the canopy of cloud which for so large a portion of the year rests upon the mountain ridges and cuts off the light and heat of the sun. Hence his harvests are often thrown into the late autumn, and in many a season his thin and scanty crops rot on the ground, leaving him face to face with starvation and an inclement winter. Under these adverse circumstances, he could hardly fail to become more or less subdued and grim.

This whole question of racial characteristics and differences is a highly complex one, controlled by many variable factors. Climate is one factor out of the many. That it plays a part, often a significant part, in the final result can not be doubted. The fascinating element in the whole discussion is the effort to determine, quantitatively, the value of the climatic factor. And this determination, in the present stage of human knowledge, seems impossible.



DR. THOMAS HUNT MORGAN

PRESIDENT OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE PROGRESS OF SCIENCE

THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE AT DES MOINES

THE very successful Des Moines meeting was one of those coming in alternate years which are intended to carry the work of the association to a new or more remote center, in order that the good news of science may be spread and scientific men may have opportunity to learn about all parts of the country. The association meets once in four years successively in New York, Chicago and Washington, when most of the associated societies come together. These are also the times of the quadrennial national elections and it may ultimately be recognized that the scientific meetings are national events of the same order of magnitude, for the advancement of science is more important for the national welfare than which political party is in office.

At the intervening two-year periods the meeting is in a large and accessible city; last time it was in Philadelphia, next year's meeting will be in Cleveland. Then in the alternate years the association migrates to cities that may be distant from the main scientific centers and of such size that a very large meeting could not be cared for. The meeting two years ago was at Nashville; it was expected that the meeting two years hence would be at New Orleans. At the recent Des Moines meeting the plans of the Chicago "Century of Progress" Exposition of 1933 were presented and it was decided to hold the Chicago convocation week meeting in the summer instead of at Christmas time in order that there may be cooperation with the exposition, at which science is to be made the dominant feature, and with the international congresses that are planned.

It will be remembered that the American Association formerly held its meetings in the summer, as the British Association has always done. Transfer to the winter was made largely because this was the preference of most of the affiliated societies. The country, however, is so large and the number of its scientific men has increased so greatly—the association now has over 18,000 members—that there is urgent need of two meetings a year. The distance to the Pacific coast has led to the organization of a Pacific Division which holds summer meetings; it is desirable that these meetings, or some of them, be national meetings of the whole association. There will consequently be a summer meeting at Los Angeles and Pasadena in 1931; if this and the Chicago meeting are as successful as is expected, there will be regular summer meetings, alternating probably between the east and the west.

Des Moines may seem remote to those living on the Atlantic seaboard, but Iowa, Missouri and Kansas now have the largest birthrate of scientific men and the scientific population of the central states is very large. There were no fewer than 1,500 papers presented before the fifteen sections of the association and the some twenty-five special societies meeting in cooperation with them. Scientific research, even such as is highly specialized, was thus fully represented.

The second object of the association—the diffusion of science and the scientific method and the maintenance of helpful relations between scientific workers and the larger public—was forwarded at Des Moines to an unusual degree. There were more general and popular lectures than at any previous meeting. The press service, under Dr. Austin H. Clark in cooperation with *Science Service* and

representatives of the press, was unusually good, full telegraphic reports being printed throughout the country.

Dr. D. W. Morehouse, president of Drake University and director of its astronomical observatory, was chairman of the local committee. With the cooperation of the vice-chairman, Mr. J. W. Studebaker, superintendent of public schools, Mr. Henry Nollen, chairman of the special committee on reception and entertainment, Dr. Walter L. Bierring, chairman of the committee of finance and local membership, admirable arrangements were made for the meeting. They secured the active interest of the governor of the state, the mayor of the city and its leading citizens. Everything possible was done to add to the pleasure of scientific men from a distance. More than four hundred citizens became associate members of the association for the meeting, a record never hitherto approached, and the attendance at the special addresses and more popular lectures was numbered by the thousands.

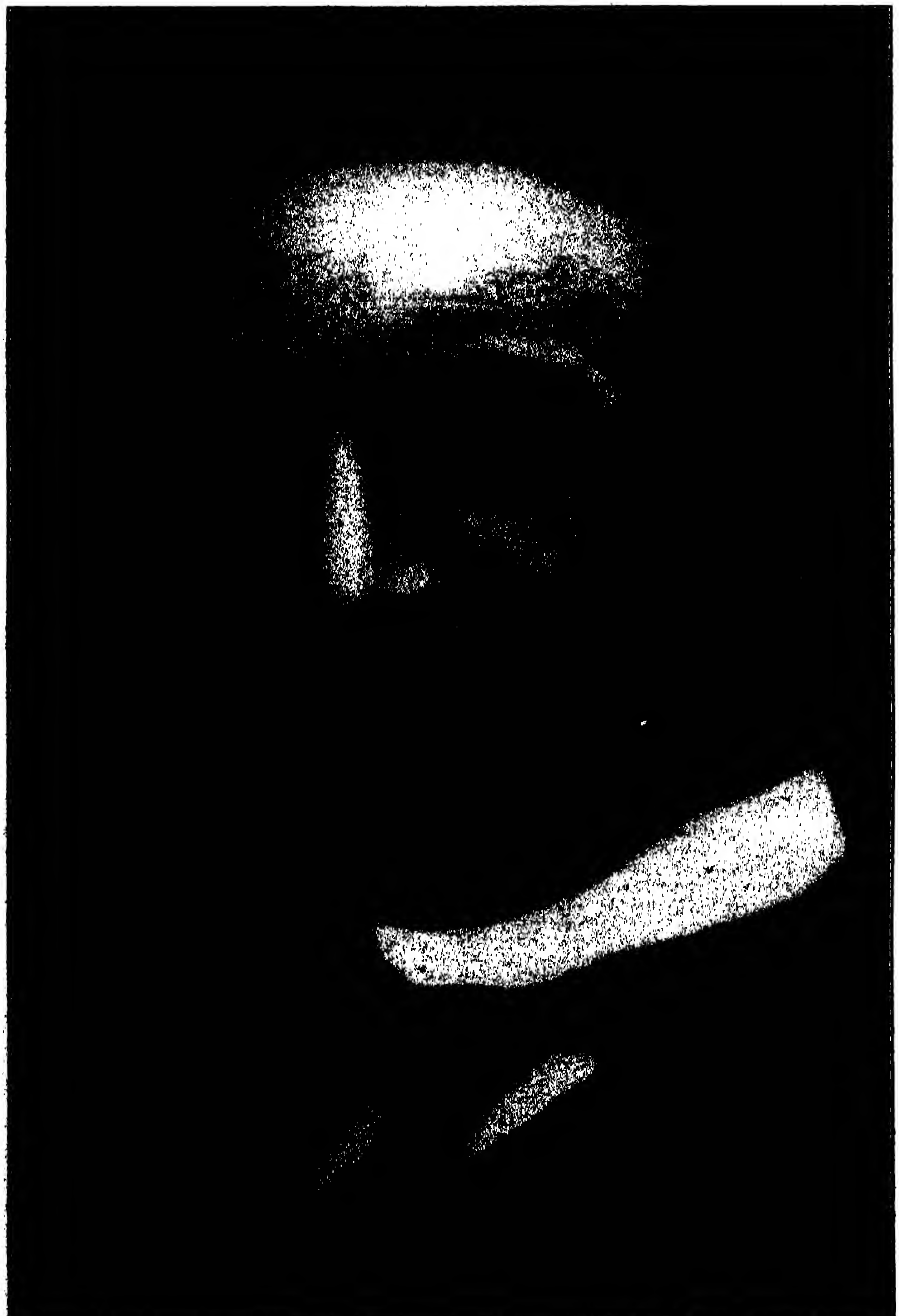
The association in turn had provided a program of general interest. The address of the retiring president, Dr. Henry F. Osborn, president of the American Museum of Natural History, at the opening session was on "The Discovery of Tertiary Man." On Sunday afternoon the president of the association, Dr. Robert A. Millikan, director of the Norman Bridge Laboratory of the California Institute of Technology at Pasadena, gave a lecture entitled "The Alleged Sins of Science." Dr. George H. Parker, of Harvard University, gave the Sigma Xi lecture on "Some Aspects of Human Biology," and Professor Irving Fisher, of Yale University, the Josiah Willard Gibbs Lecture on "The Application of Mathematics to the Social Sciences." There were in all twenty-two general and non-technical lectures, the speakers including Professor Edwin B. Frost, director of the Yerkes Observatory, Professor A. E. Kennelly, of Harvard University, and other distinguished men of science.

Dr. Thomas Hunt Morgan, director of the Kerckhoff Laboratories of Biological Sciences of the California Institute of Technology, until recently professor of experimental zoology at Columbia University, was elected president of the association to preside at the meeting to be held next year at Cleveland. The distinction of Dr. Morgan in scientific research has already been marked by his election to the presidency of the National Academy of Sciences, an office that has been held by only two other living men of science, Professor Michelson and Dr. Welch.

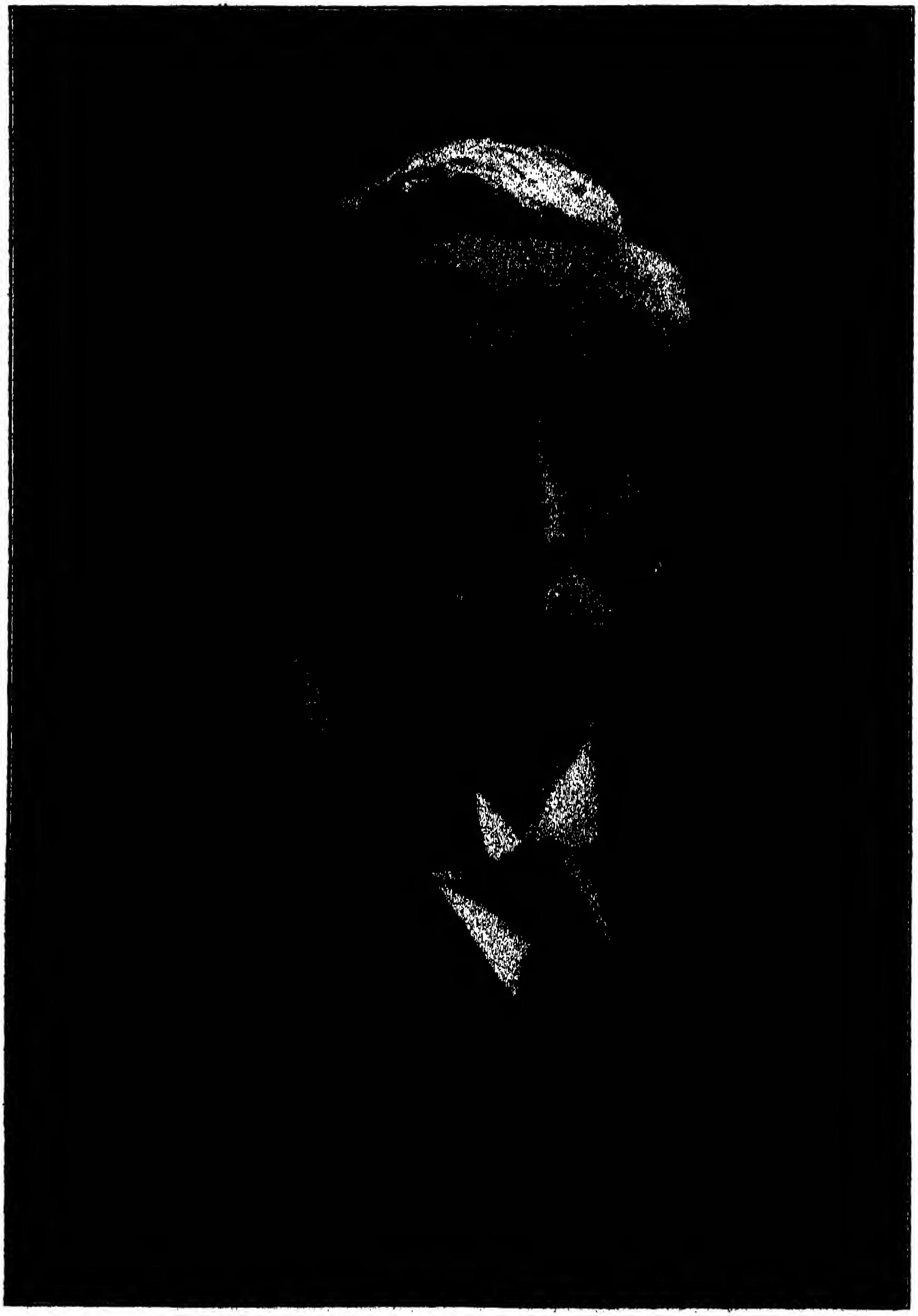
NOBEL PRIZES FOR PIONEERS IN THE FIELD OF VITAMIN RESEARCH

We owe the word "vitamine" to Casimir Funk, but when Funk published his most comprehensive account of this subject he was at pains to dedicate it to Christian Eijkman. The volume of research publications on the relation of vitamins to nutrition is now enormous, but whoever reviews its significant papers turns first to a single paper by F. Gowland Hopkins in the *Annalist* of 1906 and cites it and him as the first to recognize the existence and significance of these factors in nutrition. It is, then, peculiarly gratifying to workers in the field of vitamin research that these two pioneers have been honored by the award of the Nobel Prize in Medicine.

Students of the subject will recall that the beginnings of vitamin research had a multiple origin. The problem of beri-beri antedated by some years the problem of vitamins, or "accessory factors" as Hopkins called them, in normal nutrition. Beginning with Takaki, in 1878, the dietary origin of beri-beri became progressively evident. Much of



FREDERICK GOWLAND HOPKINS
PROFESSOR OF BIOCHEMISTRY AT THE UNIVERSITY OF CAMBRIDGE



CHRISTIAN EIJKMAN

Professor of hygiene and legal medicine at the University of Utrecht

the pioneer work on its etiology centered in Java. It was there that the Englishmen, Fraser and Stanton, made their classic contributions. It was in the Dutch Station in Java that Christian Eijkman entered the picture and in 1898 demonstrated that the disease could be actually produced in fowls by dietary measures. Human beri-beri is rarely uncomplicated, is usually a syndrome of symptoms due to multiple deficiencies. Human subjects therefore made difficult clean-cut relation between specific cause and specific effect. Eijkman's discovery made it possible to place the study on a scientific experimental basis. He gave us an experimental animal to work with and the prodigious strides since 1928 are perhaps due more to this one contribution than to any other single discovery. It is logical and fitting that two of his successors in the Java Station, Jansen and Donath, have been the first to isolate a crystalline anti-beri-beri substance of proven efficacy.

The contributions of Frederick Gowland Hopkins to prophylactic nutrition extend far beyond the field of vitamin research. The work of Osborne and Mendel in this country was directly stimulated by Hopkins' theories about the quality of proteins in diet. The use of white rats by Hopkins in his protein quality studies led him to postulate the existence of "accessory factor" in 1906 and to recognize the existence of such factors in milk. This discovery in turn was directly responsible for the use of "protein-free milk" by Osborne and Mendel in their studies of the significance of individual amino acids and ultimately to the separation of what we now call vitamins A and B. To vitamin research workers the Nobel Prize award to Hopkins for initiation of work in this field is singularly appropriate.

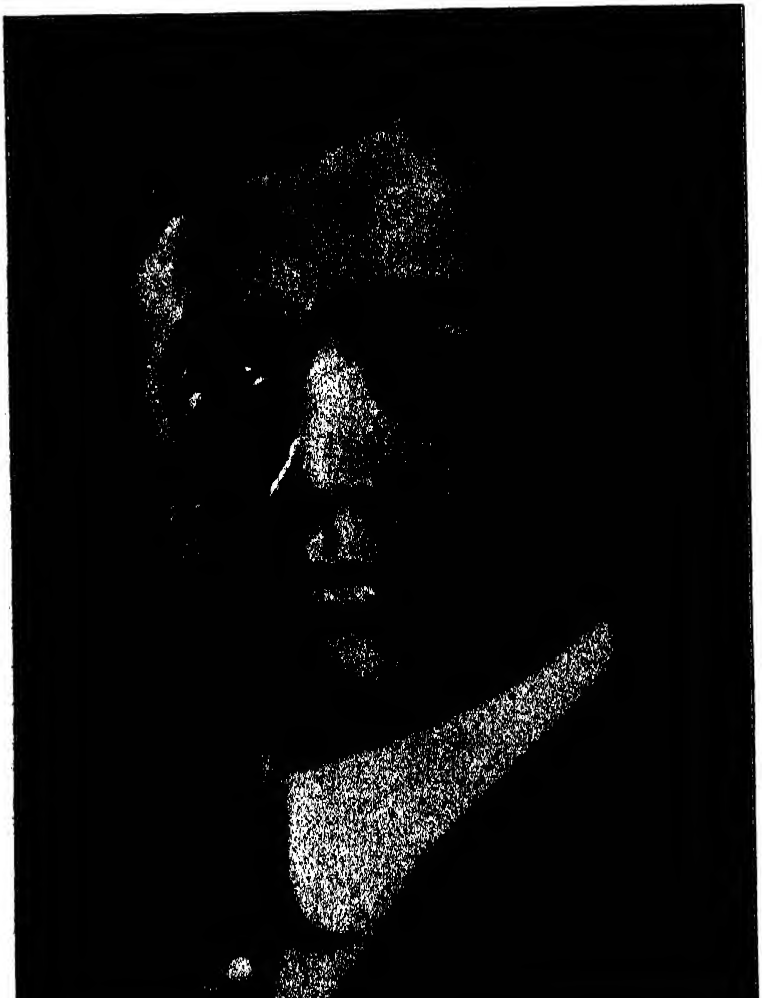
At the same time it is to be granted that the award might have been made to him on any one of a great variety of bases. His work on uric acid and its quantitative estimation, his discovery of tryptophane, his work on the significance of protein quality, his studies of the Bence-Jones protein, of xanthine oxidase, and in recent years his isolation of glutathione from muscle and his classic collaborations with Sir Walter Fletcher into the nature of biological oxidations; any one of these would have justified the recognition of Sir Frederick Hopkins as outstanding in the field of biochemistry.

The apportioning of recognition and responsibility for scientific achievement is far more difficult to-day than in earlier years. To-day contact between workers and laboratories is much more intimate. Secrecy and cloistered effort has been replaced by openness and group effort. Ultimate solution of almost any problem is almost inevitably to-day the resultant of a combination of brains and laboratories often widely separated geographically. It is rare, then, that in crowning success the lines of responsibility for leadership and inspiration lead so clearly and so directly to single men as in the present case. The world over there has been immediate and satisfied rejoicing that the Nobel Prize award has singled out Frederick Hopkins and Christian Eijkman.

W. H. E.

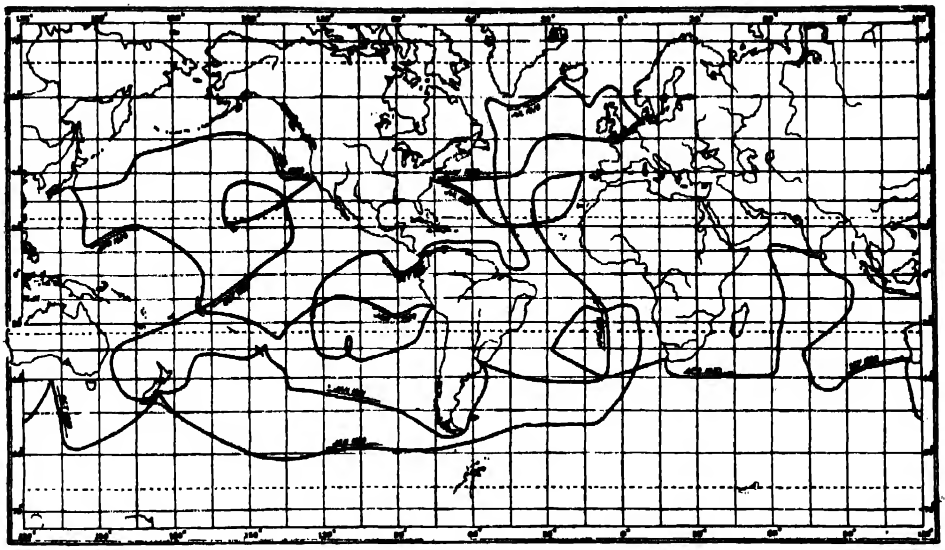
THE LOSS OF THE CARNEGIE AND THE DEATH OF CAPTAIN AULT

THE destruction by explosion and fire of the non-magnetic yacht *Carnegie* and the tragic death of its commander, Captain James Percy Ault, in the harbor of Apia, Western Samoa, is a serious loss to science, not less so because the larger part of the wide-reaching program of the Carnegie Institution of Washington had been accomplished. An article by Captain Ault on the purpose and progress of the ocean survey under his charge was published in THE SCIENTIFIC



JAMES PERCY AULT

LATE COMMANDER OF THE "CARNEGIE"



TENTATIVE ROUTE FOR SEVENTH CRUISE OF THE "CARNEGIE"

MONTHLY for February, 1928. Up to that time the *Galilee* had covered more than 73,000 miles during three cruises in the Pacific Ocean from 1905 to 1908, and the *Carnegie* more than 291,000 miles during six cruises in all oceans from 1909 to 1921.

Two months after the publication of this article the *Carnegie*, under the command of Captain Ault with eight scientific men and seventeen seamen, left Washington for a cruise of three years over the oceans of the world as shown on the accompanying map. The vessel, built twenty years before, had been completely overhauled and reconditioned. Laboratories had been added to provide for a broadened program of study which included several of the newer branches of oceanographic research. Four years had been spent in preparing for what was to have been the last cruise of the vessel under the Carnegie Institution, inasmuch as it was intended that future expeditions would be dispatched under other auspices.

A year and four months later a body of distinguished scientific men, headed by President Merriam, gathered on the *Carnegie*, at San Francisco, to greet Captain Ault and his staff and to felicitate them upon their progress. A program aboard the ship in celebration of the twenty-fifth anniversary of the founding of Carnegie Institution and of certain of its major departments of research, among them the department of terrestrial magnetism, under the supervision of which the *Carnegie* was designed, constructed and operated.

The yacht had put in at San Francisco for reconditioning preparatory to entering upon the last and longest stretch of the cruise. In conformity to program the vessel had encircled the North Atlantic, had passed through the Caribbean Sea and the Panama Canal, had cruised in the southeastern, central and northern regions of the Pacific, and had touched at many points in the Pacific including Easter Island, Peru, Tahiti, Guam, Samoa and Japan. Of the estimated 110,000 miles of the three-year cruise, 43,000 miles had been covered.

A wireless from Captain Ault on September 23 reported safe arrival at Hono-

DESTRUCTION OF THE "CARNEGIE"

lulu. A cable from Pago Pago, Samoa, on November 27 stated that the expedition was leaving that port. On the morning of November 28 the vessel anchored in the harbor of Apia, Western Samoa. All was well with ship and staff. Twenty-four hours later appeared the message which made known to the world that for the *Carnegie* and her commander the voyage had forever terminated.

In concluding an account of the last voyage of the *Carnegie* and an appreciation of Captain Ault, John A. Fleming, acting director of the department of terrestrial magnetism, and Frank F. Bunker, editor, of the Carnegie Institution of Washington, say:

"It is not often that a man's qualities of temperament and character fit him completely for the work he does. Perhaps it would be more correct to say that rarely does opportunity provide him with that work for which, by nature and training, he is best qualified. However that may be, those who knew Captain Ault intimately and worked with him are a unit in declaring that never was there a finer illustration of that accord betwen worker and work which brings inevitable and unquestioned success.

"Captain Ault had a rugged physique and a commanding presence. He possessed forcefulness, resourcefulness and the ability to make quick decisions. Gifted to an unusual degree with the qualities of leadership he was, withal, sympathetic, kindly and broadly tolerant. He was a gentleman of the finest type who quickly won the friendship, good will and cooperation of all. Moreover, he was skilled in navigation, abreast of general scientific thought, and an authority in his own field. Could there have been a combination of qualities more splendidly suited to a commander of the *Carnegie*?"

THE SCIENTIFIC MONTHLY

MARCH, 1930

FIVE DAYS OVER THE MAYA COUNTRY

By Dr. A. V. KIDDER

CHAIRMAN, DIVISION OF HISTORICAL RESEARCH, CARNEGIE INSTITUTION OF WASHINGTON

COLONEL LINDBERGH'S recent air survey of the Maya region of Central America is a fine example of the value of team play, for when a great aviator, a great transportation company and a great scientific agency all put their shoulders to the same wheel, that wheel is bound to turn. The project grew from a combination of interests, a focus of attention upon a single objective: Colonel Lindbergh, always keen to demonstrate the utility of the aeroplane and especially intrigued by glimpses, during a former flight, of ancient jungle-buried cities; Pan-American Airways, Inc., spreading its network of flying-trails in Latin America and keen to forward any project contributing to scientific knowledge of and popular interest in the regions it serves; Carnegie Institution, whose staff archeologists had labored earth-bound in the forests for years

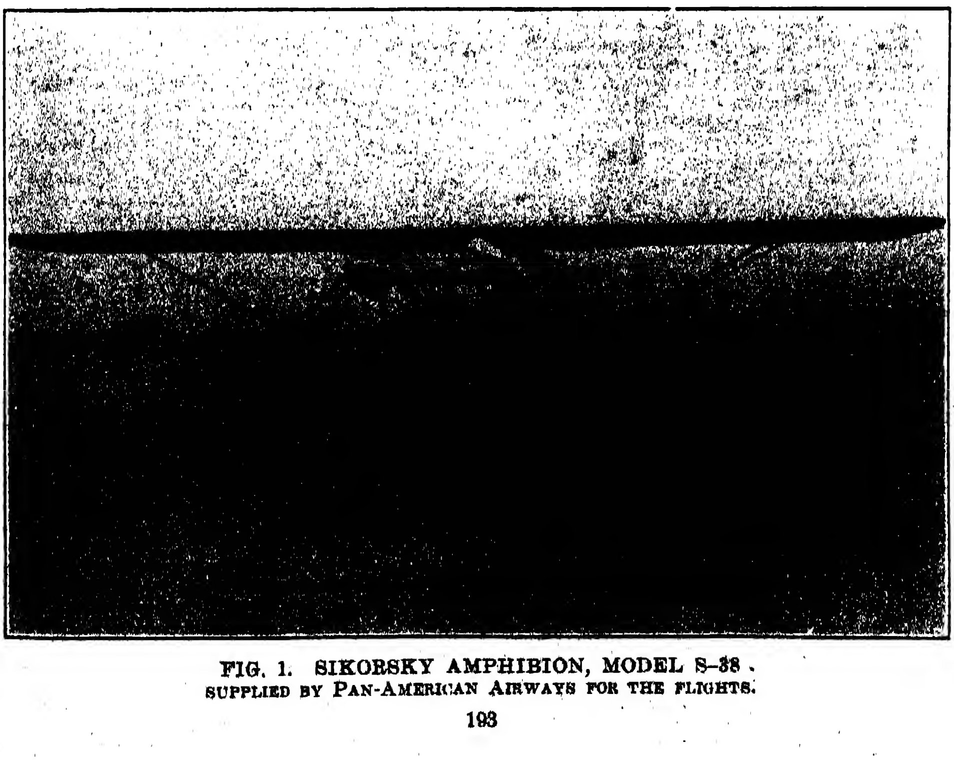


FIG. 1. SIKORSKY AMPHIBION, MODEL S-38. SUPPLIED BY PAN-AMERICAN AIRWAYS FOR THE FLIGHTS.

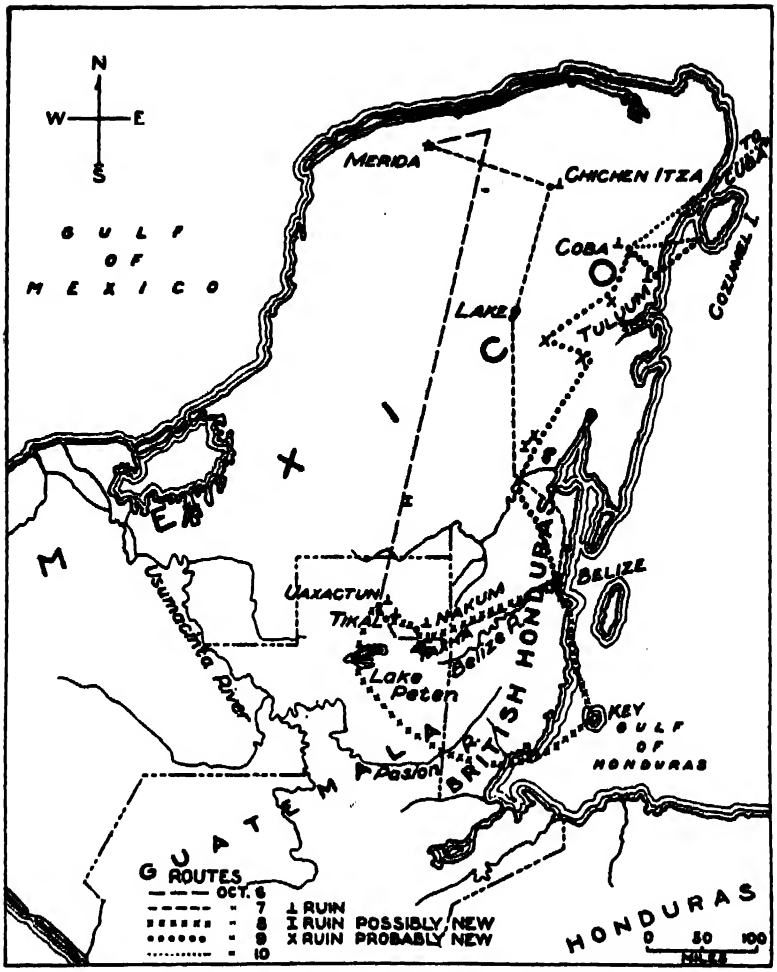


FIG. 2. MAP OF THE MAYA REGION

SHOWING THE COURSE OF THE DAY-BY-DAY FLIGHTS OF COLONEL LINDBERGH'S PARTY AND THE LOCATION OF RUINS OBSERVED AND PHOTOGRAPHED.

longing for the sweeping view of their field obtainable only from the upper air. Such was the team that organized itself during the early autumn for the flights just accomplished.

Belize, once a stronghold of buccaneers, now capital of British Honduras and an important base of the Pan-American, was the rendezvous. We met there on October 5. Colonel and Mrs. Lindbergh were finishing their swing around the Caribbean. Oliver Ricketson, Carnegie Institution archeologist, came down from his headquarters in Guatemala City; W. I. Van Dusen, of Pan-American Airways, and the author flew down from Miami. That evening we laid plans and gathered equipment.

Our general objectives were to test the aeroplane as an agency for archeological exploration in tropical countries and to determine whether or not the ruins of Maya cities could be located from the air. And above all things we

FIG. 3. TEMPLE AT TIKAL, GUATEMALA
THE VERY HIGH PYRAMID UPON WHICH THE STRUCTURE RESTS IS ENTIRELY BURIED IN THE JUNGLE. THE TIKAL TEMPLES WERE USED AS A STARTING POINT FOR THE NORTHERN FLIGHT.

wished to get an idea of what the Maya country really looks like, for in spite of the fact that archeologists have for many years been pushing their way into that region, they have been so buried in the welter of forest, their outlook has been so stifled by mere weight of vegetation, that it has been impossible to gain a comprehensive understanding of the real nature of this territory, once occupied by America's most brilliant native civilization. Such understanding is absolutely necessary, because all people, ancient and modern, are largely products of their environment; hill and plain, watercourse and cultivable land shape the destinies of nations more powerfully than do kings and battles. And of the Maya country as a whole, of the "lay," so to speak, of the land, we have had, until Colonel Lindbergh's flights, only the scantiest sort of knowledge. The labors of many explorers and scientists have, however, given us an outline of Maya history, have made clear the fact that well before the time of Christ there arose in the New World an independent civilization based on the cultivation of corn which culminated at the great cities of the Maya Old Empire. These cities were built and occupied while Europe was in the Dark Ages, but they, like Rome, fell, and their high tower temples and many-chambered palace monasteries were engulfed by the jungle. The Maya people then moved northward into what is now Yucatan, took on a new lease of life and again constructed cities, many of which persisted until the coming of the Europeans put an end to all native American development.

Our problem was clear. We must cover as much of the area as possible, and learn as much as possible about it.

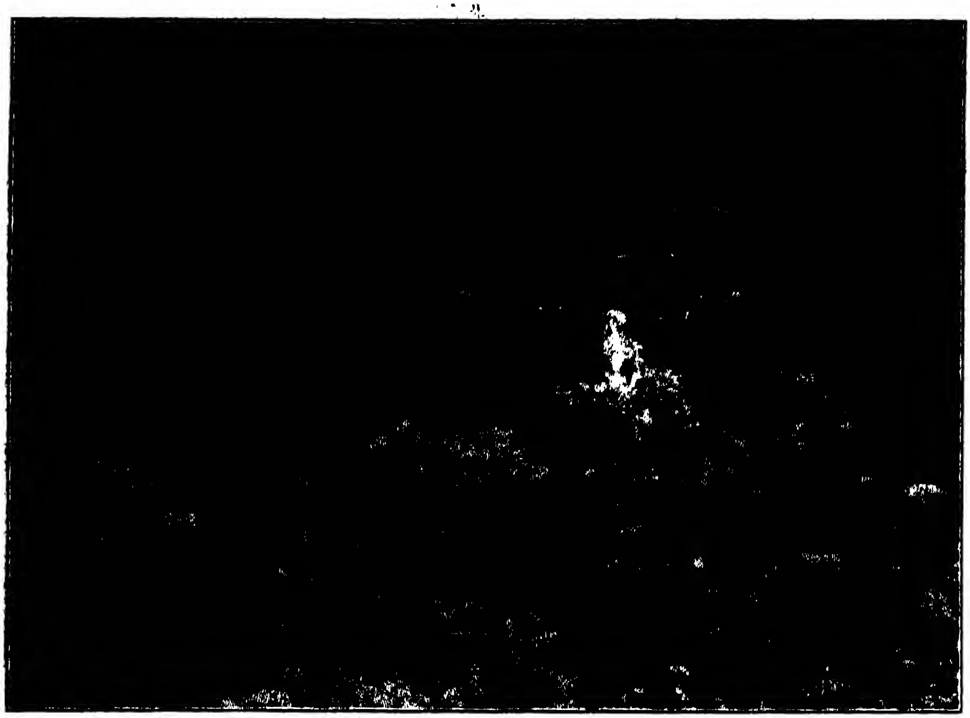


FIG. 4. ANOTHER TIKAL TEMPLE
THE BUILDINGS OF THIS CITY STAND CLEAR ABOVE THE TREE-TOPS AND ARE VISIBLE FROM THE AIR FOR OVER TWENTY MILES.

Our equipment was ideal, a Sikorsky amphibion from the Pan-American fleet, capable of sustained flight with either of its twin motors (Fig. 1). It carried radio, collapsible rubber boat and emergency rations—to which Colonel Lindbergh with characteristic thoroughness saw to it that there was added a shotgun, in case a forced landing made it necessary to live on the country—hammocks, cooking kit, canteens, medicines and machetes.

The general plan was to strike first into the heart of the Old Empire region in northern Guatemala and then turn north to fly the entire length of Yucatan in a single "hop" (Fig. 2). This would necessitate refueling at Merida at the extreme northern end of the peninsula, and as the distance was so great and landing-places were probably non-existent, weight had to be cut to a minimum in order that should one engine fail, the plane could be counted upon to "hold up" for several hundred miles. Van Dusen and I, therefore, stayed behind, and Ricketson, an old hand at Peten travel, was to do the observing.

Taking off from the harbor of Belize the morning of October 6, the course was laid directly up the Belize River, cutting straight across its thousand loops and bends, high above the rapids and shallows that make boat travel so slow. A hundred miles inland the plane turned northward and in a few minutes there became visible the roof-combs of the temples of Tikal, greatest of Old Empire cities (Figs. 3, 4). After circling low for photographs, a straight shot was made for Uaxactun, the oldest known Maya city, discovered in 1920 by Dr. S.

G. Morley, of the institution staff, where Ricketson has excavated for the past four years. From Tikal to Uaxactun is a very long day's journey by mule train, a journey possible at all only if the trail has recently been cleared. The Sikorsky did it in exactly six minutes! Ricketson's clearing and camp (Fig. 5) and the strange, squat, grotesquely sculptured pyramid which he has laid bare were clearly visible, and were photographed as Lindbergh wheeled close above the tree-tops (Figs. 6, 7).

Beyond Uaxactun lay unknown, uninhabited country, and the distance to Merida was so great that no deviation could be made from a direct northward course. The sea of jungle proved to be unbroken. Hour after hour the green floor of the tree-tops flowed back under the speeding plane (Fig. 9). Ninety miles beyond Uaxactun there was made out a flat-topped pyramid surmounted by two temples, the culminating structure of a forgotten and forest-swallowed city.

Northward again over vast stretches of green, until the palm-thatched huts of the first small frontier settlements of Yucatan were reached, and every one breathed a little easier in the feeling that they were again over the homes of living men. Thence onward the towns became larger and the forest was dotted with the clearings of Indian corn-fields, until Merida came into sight and the plane, almost on its last gallon of gasoline, settled down upon the landing field.

The party were overnight guests of Governor Torre Diaz, who has done so much to forward the institution's work in Yucatan. The first objective of the next day was Chichen Itza, largest of New Empire cities, whose temples and

FIG. 5. CARNEGIE INSTITUTION'S EXCAVATION CAMP AT UAXACTUN, GUATEMALA. THE PLANE BANKED AT THE INSTANT MR. RICKETSON TOOK THIS PICTURE.

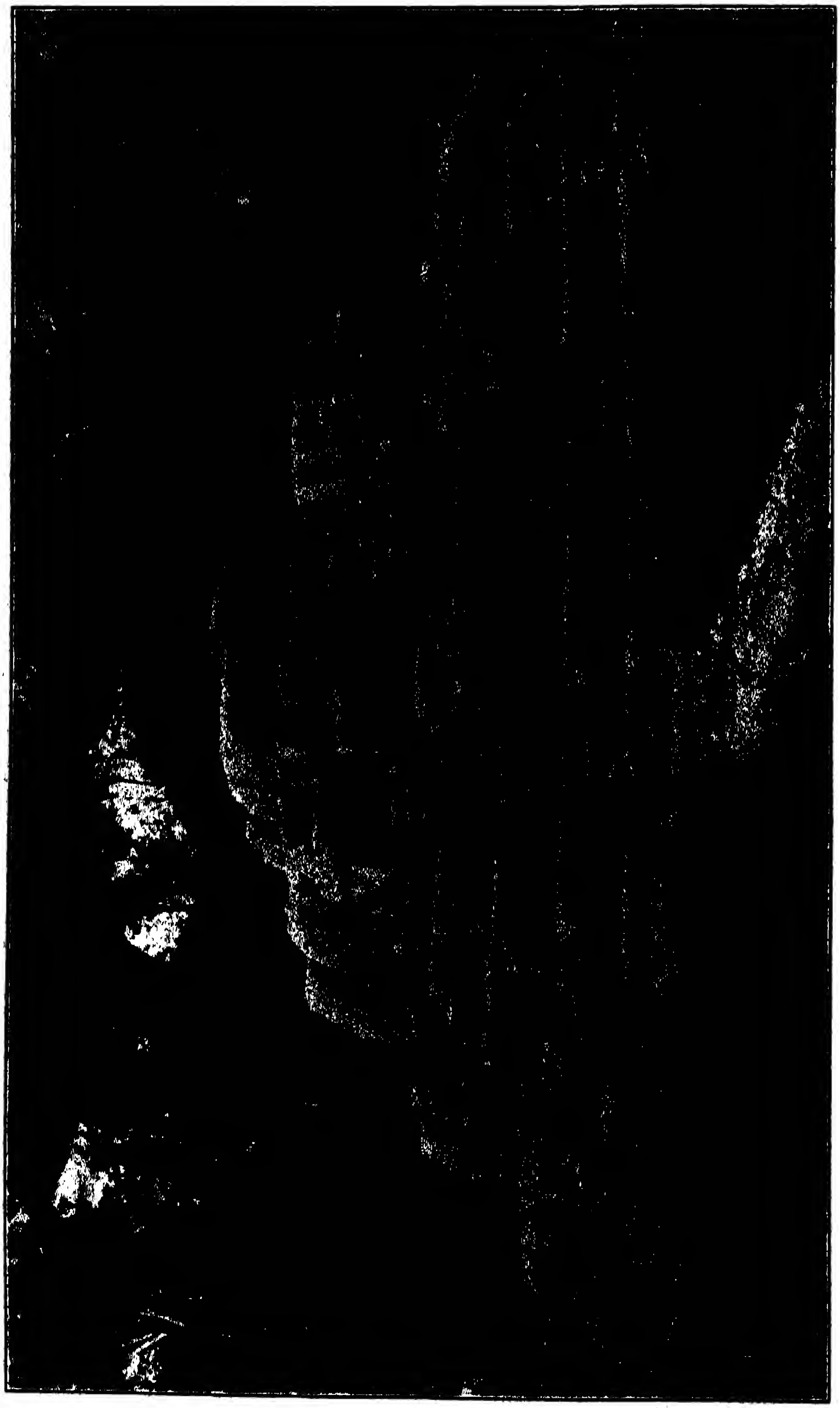


FIG. 6. GROUND PHOTOGRAPH OF THE UAXACTUN PYRAMID

THIS REMARKABLE STRUCTURE, THE OLDEST KNOWN EXAMPLE OF MAYA ARCHITECTURE, OWES ITS SPLENDID PRESERVATION TO THE FACT THAT IT WAS BURIED IN ANCIENT TIMES BY THE ERECTION OVER IT OF A LARGER PYRAMID, WHICH WAS REMOVED IN 1927 BY MR. RICKETSON'S PARTY.

FIG. 7. STUCCO PYRAMID AT UAXACTUN
WITH TRENCHES IN THE PLAZA IN FRONT OF IT.

pyramids, cleared by the Mexican government and by the institution under Dr. Morley's direction, showed snow-white against the green "bush" (Fig. 8). Thence southward to Belize, east of the outgoing route, across country hitherto untraveled, country so densely overgrown that no trace of ruins could be discerned.

The flights of the first two days covered nearly 850 miles, much of it over regions never traversed by white men and none of it ever seen from the spreading view-point of the air. At our conference on the evening of the return to Belize we decided that we must train ourselves more fully to recognize tree-shrouded mounds and pyramids, to pick out from above the vague, masked outlines of plazas and temples. And so on the eighth we struck again for the Peten and searched for ruins whose general location was known. In this way there were picked up Yaxha and Nakum, and by repeated low circling we taught ourselves this new technique of sky-spying. Thence off again to Tikal and Uaxactun, eastward to what we believed to be a ruin that could be seen on the skyline from above Uaxactun, but which turned out to be merely a group of large trees; and so to the Laguna de Peten (Fig. 10), where the Guatemalan outpost town of Flores crowds a tiny island in the lake. We paid our respects to the governor, who came out in a launch to greet us, surrounded by the entire population in dug-out canoes (Fig. 11), and then rose to fly southward over a vast flat stretch of alternating savanna and woodland, toward the northern tributaries of the Pasion River. These streams traverse a terrible and (to fly over) a most terrifying country (Fig. 13), a confused

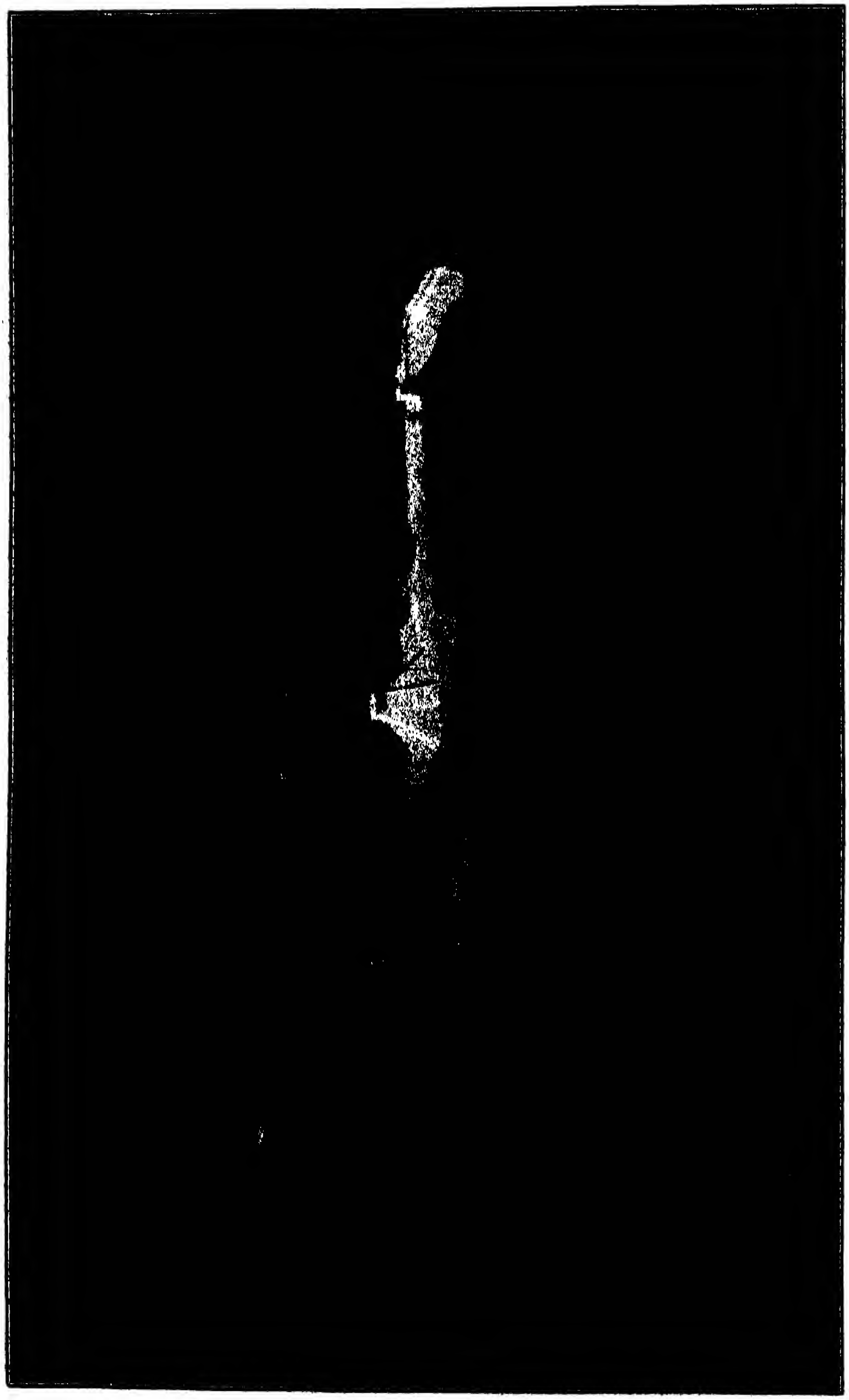


FIG. 8. RUINS OF CHICHEN ITZA FROM THE AIR
NOTE THE VERY CHARACTERISTIC TEMPLE-TOPPED PYRAMID "EL CASTILLO."

FIG. 9. THE GREAT PLAIN LYING NORTH OF UAXACTUN
A REGION ENTIRELY UNEXPLORED SAVE BY THE AIR CROSSING OF OCTOBER, 1929.

welter of gorges and limestone pinnacles smothered in a jungle so dense, so intertwined, so utterly hopeless to penetrate save through the foot-by-foot hacking of trails, that I think no one of us failed to give a sigh of relief when we soared over an outlying spur of the Cockscomb Mountains, dodged between two rain-squalls and saw to the eastward the silver shine of the sea.

The next few minutes brought one of those incredible transitions possible only to the air traveler. We swung to the north, dipped across the coastline and took the smooth water at a little key miles out in the Gulf of Honduras; anchored the plane, pumped up the rubber boat and rowed ashore. A half hour after being over that ghastly, broken, interior wilderness, we were comfortably cooking lunch under the palms by the coral beach.

The fourth day we took off a little after ten, passed northward over the coastal swamps, turned inland and in an hour were beating across the jungle west of Lake Bacalar, where, thanks to our practice of yesterday, we were able to pick up three sets of mounds, one of which was evidently the center of a very extensive city. There were four high pyramids, upon two of which could be glimpsed the white walls of temples. Colonel Lindbergh then climbed to two thousand feet and headed north across the great flat plain of Yucatan. There were no hills or valleys to break the even spread of the tree-tops, and we at once began to see the sharp eminences of ruins. I quote from the air-notes:

Sharp pyramid on N. horizon (12.05); small lakes to N. (12.07); another small lake about 6 mi. E (12.16). Now coming over pyramid (it was visible 20 miles away)—group is of

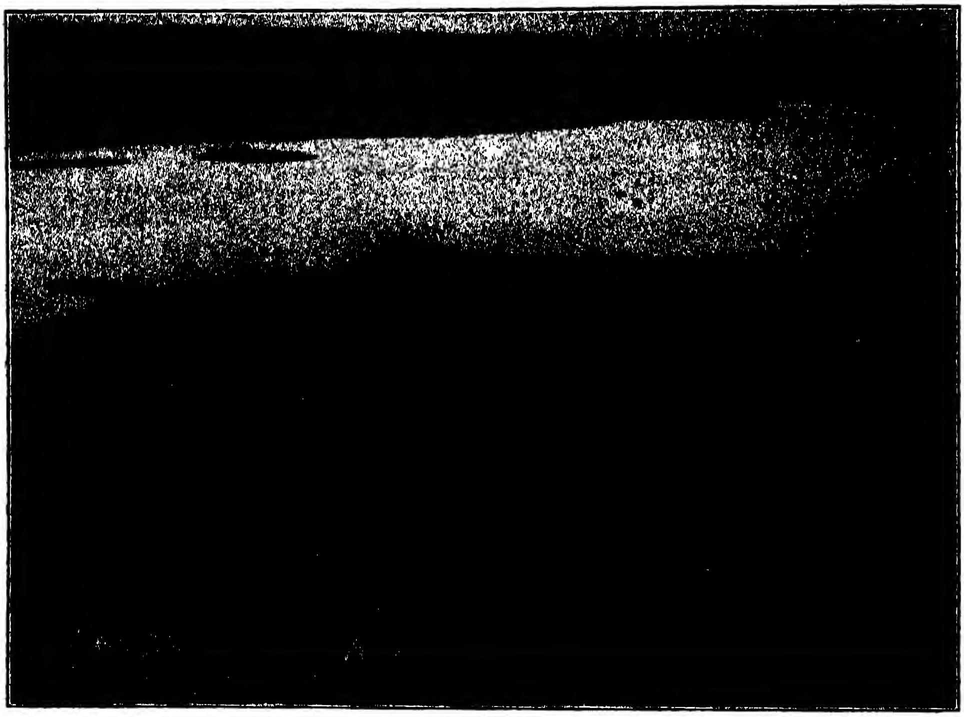


FIG. 10. LAKE PETEN SEEN ACROSS TAYASAL PENINSULA
MOUNDS OF MAYAN CITY OF TAYASAL IN FOREGROUND.

one large pyramid with three smaller ones 100 yards E. of it on a plaza (?). Indian village (6 palm-leaf huts in clearing) just (2 mi.) W. (12.20) Off N., bush dry and gray, low, and can see ground now and then between trees. High bush seems to have ended at last site. (12.29) Circled low over Indian huts, people running into houses and into bush. (12.35) Six-house village. (12.37) Bush dry and deader looking than ever, think some of these trees must shed leaves at this season. Small rain-squalls all about. (12.39) Large low mound directly below in Indian clearing. (12.43) Turn due W. toward high pyramid sighted by Mrs. L. and now heading for it across uninhabited country. (12.49) Another pyramid to N. of first one.

These groups, most of which are probably new, were located by compass-course and flying time and in some cases further marked by bearings on distant landmarks.

And so on. For an hour or more we tacked back and forth, noting sites in all directions, flying close over the largest ones and gradually working north until we saw poking up on the horizon the enormous mounds of Coba. By one-thirty we were over it, anxious to land on one of the two little lakes about which the great forest-buried buildings are grouped, for Coba has been visited by less than a dozen white men. We dipped and skimmed the water, but Colonel Lindbergh shook his head at the high trees on the farther shore and we rose again to circle the tall *castillo* and cross in a split second a swampy lowland that three years before had cost Eric Thompson and me a full hour of bitter, sweating struggle.

Up till now every one had been too busy to think of lunch, but when we swung high again and headed for the coast Mrs. Lindbergh produced choco-

late, crackers and coffee, and by the time we alighted in the ocean to go ashore at the seaside ruin of Tuluum (Fig. 12) we were well fed. That night we spent at Cozumel Island, where the Pan-American has a base, revisited Coba the next morning to recheck our observations and by ten o'clock were headed for Cuba, Miami and home.

During the flights every one was constantly busy; Colonel Lindbergh with the map on his knees kept track of courses, wind-drift, and estimated distances to and between objects sighted; Mrs. Lindbergh, whose eyes are very keen, watched the bush like a hawk, and took the photographs; Van Dusen, through Ehmer, the crack radio operator, sent bulletins of progress to the Pan-American bases at Miami and Belize, while Ricketson and I filled notebooks as fast as we could write, jotting down observations on topography, nature of forest, occurrence of lakes, streams, swamps and descriptions of the appearance from the air of the ruins passed over. The greatest thrills of our five days' flying came, of course, from the finding of hitherto unrecorded groups of Maya buildings indicating the presence of ancient cities. But the purpose of the expedition was much more than the mere discovery of sites. It was planned and carried out as a test, a reconnaissance, to gauge the value of the aeroplane for survey and observation work, and it proved that the plane is of unique usefulness in enabling one to study the country as a whole, to record its geography, to note the nature, distribution and extent of its forest types and to plan routes and fix landmarks for ground exploration. Finally, it is certain that the plane can in many regions

FIG. 11. PEOPLE OF TAYASAL.

CAPITAL OF DEPARTMENT OF PETEN, GUATEMALA, COMING OUT TO THE PLANE IN DUGOUT CANOES.

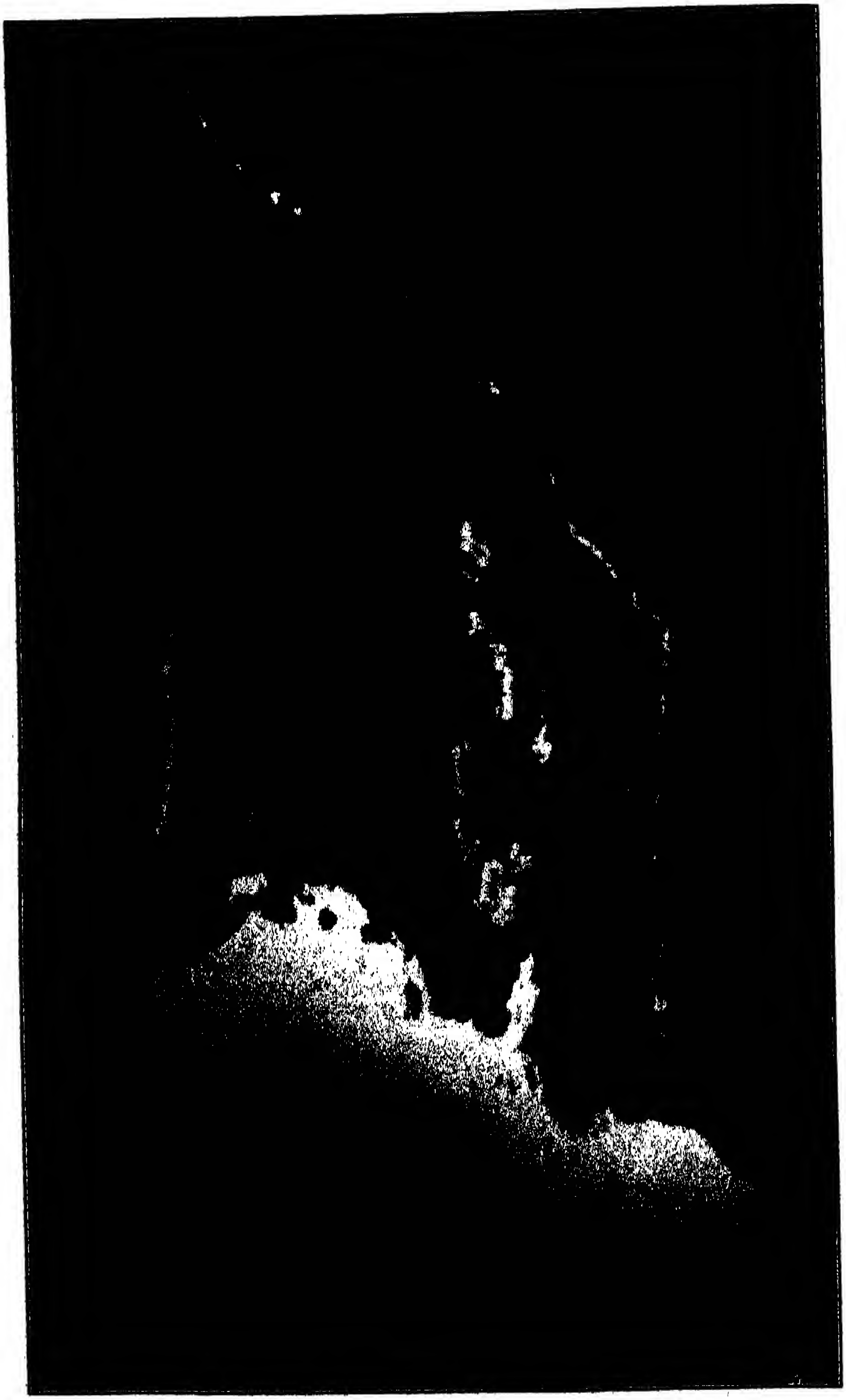


FIG. 12. RUINS OF TULUUM ON THE EAST SIDE OF YUCATAN

NOTE WATCH-TOWERS AT THE CORNERS OF THE GREAT MASONRY WALL ENCLOSING THE TEMPLE AREA.

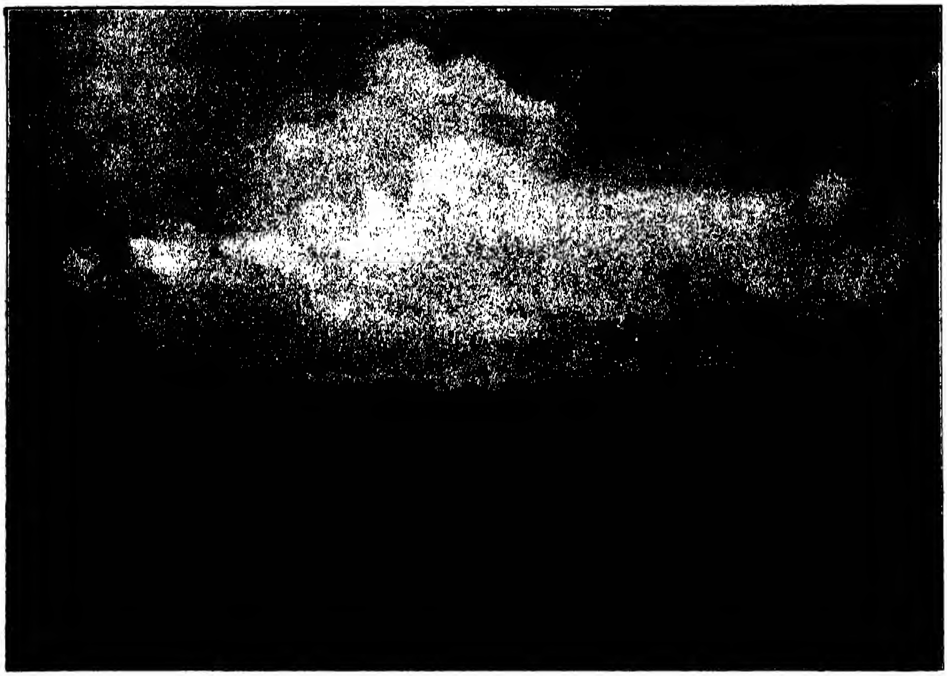


FIG. 13. BROKEN COUNTRY SOUTH OF LAKE PETEN

A HILLY REGION COVERED WITH DENSE JUNGLE AND OFFERING NO POSSIBLE LANDING PLACE.

serve to transport, set down on lakes or savannas and pick up again small parties of workers, thereby enabling them safely and easily to cover in weeks territory which would require months and whole seasons of difficult ground travel.

MODERN ASTRONOMY AND THE PROBLEMS OF STELLAR EVOLUTION

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THE ultimate object of pure astronomical investigation is to determine the form, motions and physical constitution of our universe, in the broadest sense. Even its limits are unknown and no serious scientist would be so bold as to attempt to set them any more than he would to the ultimate form which man himself will acquire under the influence of evolution.

Evolution plays its part in the acquisition of knowledge of our universe as truly as in biology, although of course not in the same sense. The ancients first occupied their awakening scientific intelligences with the geographical features of their immediate neighborhoods and very naturally concluded that the earth was flat, which conclusion brought a large crop of difficulties when they tried to explain the motions of the Sun and Moon.

When they became more observant and took thought of the apparent forms of the Sun and Moon and of drops of water they were led to the true explanation of a spherical form for the Earth as well as for the Sun and the Moon.

With the invention of the telescope a new era was opened. Not only were new worlds revealed but almost as startling an array of new facts about the known heavenly bodies—spots on the Sun, markings on and circular forms for the planets and moons revolving around them. Saturn was seen to have a wide flat ring around it. Two new large planets, Uranus and Neptune, were discovered. Stars were multiplied by thousands, and they were seen to be of all colors. The few nebulous spots visible to the unaided eye were also increased to thousands. Structural details were observed in the bright comets, and comets so faint that they could not be seen without a telescope were found to be more numerous than bright ones.

The ring of small planetoids was discovered. Stars were seen to be double and multiple, and groups containing thousands were revealed.

Graduated circles were added to the telescopes and more accurate positions of all heavenly bodies obtained. The screw and the spider thread were brought into play, and the diameters of planets and small distances between stars and other objects were determined with accuracy.

More light was necessary to see faint objects better, and with the larger telescopes still fainter objects were discovered until we have the giant telescopes of to-day.

The dispersive power of the prism was applied to the analysis of light and we have the spectroscope, one of the most powerful and far-reaching aids to astronomy as well as to physics. The addition of photography may be said to have rounded out the mechanism for a complete reorganization of astronomical investigations.

The history of these advances is of great interest but can only be mentioned here. Neither is it possible to detail the growth of and attempts to solve the larger problems in the earlier epochs of astronomical research.

These new methods of research have now been in extensive use for nearly a half century, and the results have been so illuminating that it is possible to revise earlier hypotheses and to formulate some new ones.

As the most recent developments and those of greatest general interest have been in the great outer universe of the stars and nebulae I shall refer only briefly to the origin of the solar system.

The great work of Copernicus, Kepler and Newton placed the solar system upon a firm gravitational basis, one which stands to-day unshaken. Its origin and mode of evolution are, however, still wrapped in nearly impenetrable darkness. Of the various attempts to explain it the Laplacian nebular hypothesis has received the greatest attention and confidence. The last quarter century, however, has confirmed doubts as to its sufficiency. Laplace assumed his original nebula to extend to the outer confines of the system and to be rotating essentially as a solid body. That condition introduces the moment of momentum as a test of the hypothesis. Chamberlin and Moulton have investigated this question and find that instead of being constant in the solar system as it should be on Laplace's hypothesis, the Sun possesses only one two-hundredth part of what it should be as calculated from the outer planets.

This test is crucial and shows that the hypothesis can not be true. Chamberlin and Moulton proposed their alternative theory of the near approach of two stars and the tidal ejection of spiral arms which condensed into the planets and satellites. This hypothesis satisfies the moment of momentum test and the other observed conditions as far as known.

It has the strong argument in its favor that near approaches of stars must occur, and the prevalence of the spiral form among a certain class of the nebulae shows that some such tidal deformations do occur. In this connection it should be borne in mind, however, that no true star has been observed with such spiral arms, unless we except the planetary nebulae which show streams and structure which may be spiral, and that true spirals are nebulae of vastly greater proportions and masses than ordinary stars.

As the spiral nebulae contain by observation thousands of stars it is not rational to assume them as a class to be the progenitors of small systems like our Sun.

The planetary nebulae are now known to be composed of essentially a single star surrounded by shells and streams of nebulosity.

Investigations of the spectra of these planetary nebulae by Campbell and Moore, of the Lick Observatory, have shown that some at least of such nebulae are in rotation. In some of them the forms are quite irregular and even some sort of spiral arms can be traced.

An investigation just concluded in Córdoba of these observations shows the strong probability that the observed radial velocities of these nebulae are largely of expansion and contraction and not wholly of translation. If this conclusion is confirmed as seems probable the original Láplacian hypothesis may be modified to satisfy the observed conditions in these planetary nebulae.

There is considerable evidence to show that the planetary nebulae are the more or less stabilized conditions of the class known as temporary stars or novae. Without going into details, the most plausible hypothesis of the cause of these outbursts (and therefore probably of the planetary nebulae) is a grazing collision of a small cloud of cosmical matter with a stellar body.

If such an assumption is correct we have in the planetary nebulae potential solar systems. For such a mode of formation as that outlined provides the central sun with a small moment of momentum and the mechanism for the formation of planets and satellites with larger momenta of momentum.

Further work will be necessary to decide, but the evidence at present available favors, in my opinion, the hypothe-

sis that the planetary nebulae are the forerunners in general of solar systems such as ours. This is not necessarily, however, the only possible mode of their origin, and it may be that there are others.

The Observatorio Nacional Argentino was founded at one of the most important epochs in the science of astronomy. In the decade previous photography had been applied to the fixing of lunar detail and the positions of the stars' images automatically and free from personal bias. The advantages were obvious, and with the invention of the dry plate this method was at once applied to many problems. One of the largest pieces of work undertaken was the Carte du Ciel, a stupendous undertaking which is not yet completed. Another of more modest dimensions was the photographic Durchmusterung by Gill at the Cape Observatory and Kapteyn at Groningen, Holland. This work was completed rapidly and has been most useful.

At about the same time the spectroscope was being applied to the study of the Sun and stars in several countries, notably England, France and Germany as well as by Father Secchi in Italy. The new science of photography was applied to this new branch of astronomy also and soon proved its value. De la Rue and Lockyer in England and Janssen in France applied it to total solar eclipses with the discovery of helium by Lockyer as one of the results. Huggins especially in England applied it to the study of stellar and nebular spectra with most important results—among which was the discovery of the bright lines of the gaseous nebulae.

A little later Vogel in Germany applied photography to the spectra of the stars for the determination of their radial velocities by means of displacements of lines from the positions which such lines have when the observer and the star observed are at rest with respect to each other (the Doppler principle).

Thus it may be truly said that photography has revolutionized astronomy not only by opening up new fields which could be observed only in that way but also by its application to the determination of the positions and motions of the stars from photographic negatives which previously had been determined only by the meridian circle or equatorial (micrometer).

Not only does photography give a more rapid and accurate record of considerable areas of the sky, for example, but it also permits the observation of objects too faint to be seen with any telescope simply by increasing the exposure time. The longer the sensitive plate is exposed in the telescope, the fainter the stars and nebulae that will leave an image. And the records are permanent and may be consulted decades hence.

Many of the objects photographed today have never been seen by the human eye except on photographs. Satellites, minor planets, comets, thousands of nebulae and millions of stars have been discovered in this way, and many facts concerning all sorts of celestial bodies have been made known which would have been impossible in any other way.

As I have already pointed out, Gould's first object was the preparation of the catalogues of positions of the southern stars which were so badly needed. But he also recognized the importance of the new method of photography and applied it to the problem of the study of the motions of star clusters by taking a series of photographs of thirty-eight of the most important of these in the southern sky and measuring the positions of the stars composing them. These observations furnish an invaluable basis which together with observations at the present time will be used to determine their

motions both internal and of translation as a whole.

The preparations of the catalogues and charts proved of such magnitude that but little time was available for photographic work outside the astrographic program, and no attempt was made until recently to enter the astrophysical field. As the work on the older programs drew to a close it became possible to make plans for a large reflector with which to make suitable observations both spectroscopic and photographic of stars, and particularly of the nebulae, in the southern sky. Plans were made and funds provided in 1912 by Congress through the effort of Minister Garro and President Saenz Peña for a reflector of one and one half meter aperture. The dome was delivered as well as the glasses for the mirrors and the mounting ordered just before the war began. It was, however, impossible to finish the telescope and put it into use. Work has now been resumed on the building, and it is hoped to have the telescope in use toward the end of next year.

A reflector of 75-cm aperture of short focus especially for work on nebulae was constructed in the observatory shops and put into use in 1917.

Some valuable observations of nebulae were secured with it, but as it was mounted in one of the old domes the demolition of the old administration building in 1923 and the construction of a new one interrupted the work. A new dome is now ready, and as soon as the telescope can be mounted, work will be resumed with it.

A lamentable accident has temporarily delayed the mounting of this telescope, in which, by the breaking of the lifting apparatus, a most estimable and efficient member of the firm constructing the dome lost his life and a part of the telescope was damaged.

The advances made since the application of photography and the spectrograph to astronomy have been so rapid that the solution of many problems has been made possible and old problems have received new interpretations. The subject is too large to attempt to treat adequately in a single paper. All I can do is to give a brief outline of some of the problems and progress up to the present. Upon an understanding of these problems depends a rational formation of plans for observations to solve them.

The problems which could be investigated with advantage by the positions, motions and brightnesses only of the stars and nebulae were limited to the form, structure and internal motions of our stellar system and these only superficially. Such observations together with the law of gravitation furnished the means of determining the sizes and orbits of the bodies in our solar system with a high degree of accuracy. Thus the problem of the sizes, distances and motions in the solar system may be said to be satisfactorily solved.

The problem of the origin and constitution of these bodies is far more difficult and is closely allied to similar problems of the stars. Little definite progress on these was possible before the introduction of the spectroscope, with which the substances composing them could be determined. The analysis of their light not only showed that the planets shone by reflected sunlight and proved the presence of practically all terrestrial elements in the Sun and stars but it also permits of determining the velocities of such bodies toward or away from the observer and other facts which have been of the highest importance in the interpretation of our universe. These facts are such as could not be discovered from the old methods of observation, but in connection with those permits the study of entirely new problems as well as aiding greatly in the solution of the older ones.

For example, the spectroscopic observations have aided by combining these radial velocities determined with the spectroscope with the tangential motions derived from the old observations of position.

Such radial velocities observed with the spectroscope enabled Keeler to prove that the ring of Saturn is actually composed of small bodies, as had been concluded to be the case by Clerk Maxwell from theoretical considerations, and was not a solid or liquid body rotating as a whole. His observations of the spectrum showed that the *inner* portion of the ring was rotating faster than the *outer* portion, which would be the case if it were composed of small bodies and the reverse of what would be the case if it were rotating as a solid.

By means of similar observations the periods of rotation of some of the planets upon their axes have been determined and some of the planetary nebulae and globular clusters of stars found to be rotating.

By the same means the temporary stars which flash out so suddenly are found to be in great activity and sending out shells and clouds of hot gases with tremendous velocities.

Perhaps the most startling feature discovered by this means, however, is the very high and generally outward velocities of the spiral nebulae.

There are many interesting questions in connection with the progress of modern astrophysical problems, but time permits a consideration of some of the most important only. Attention will be confined therefore to the stars and nebulae.

Consideration of the stars comes first, naturally, although the ideal is held always in mind of connecting all evolutionary problems finally into one all-embracing explanation of everything.

Two exactly opposite hypotheses to account for the origin and evolution of the stars have found favor.

While Laplace's nebular hypothesis was formulated specifically to account for the secondary bodies of the solar system, it has been applied also to the condensation of the stars from a primitive gaseous nebulous mass and met with general favor until recently.

Its course is from a large, hot mass of gas to a cool and possibly solid comparatively small body.

Opposed to this is the well-known hypothesis of Lockyer which assumes an origin in a large, extended and cool cloud of cosmical matter which by condensation becomes hotter and brighter and whiter for a time and then loses more heat by radiation than it gains by condensation until it becomes faint and red or perhaps even cold and dark. Lockyer's hypothesis was not looked upon favorably until recent years but is now generally accepted. It does not provide for the gaseous nebulae, and this may be the principal reason why it was slow in meeting with favor. A plausible explanation has been found, and the stars and gaseous nebulae can now be accounted for in a single hypothesis.

The application of spectroscopy at once showed wide differences among the stars, which were accompanied by differences in color apparent to the eye. These different spectra were finally arranged in a sequence and lettered O, B, A, F, G, K and M, in which the O and B type stars are blue and white with only a few lines, generally of hydrogen and helium. The lines of other substances become frequent from A type to M, and the colors change through yellow and orange to deep red in the M type stars.

These differences of color and spectrum are now known to be due to differences of temperature, the blue and white stars being very hot and the yellow and red stars relatively cool.

We have now to consider the distribution in the sky of these different spectral

classes which undoubtedly is an important factor in any hypothesis as to their relationships. The F, G, K and M type stars are fairly evenly distributed over the sky, but not so the O, B and A type stars. These types have a strong preference for the region of the Milky Way. The A type stars begin to show such a preference which in the earlier subdivisions is very marked, a preference which becomes more marked in the B class stars and still more marked in the O type stars. These latter are confined to a narrow belt along the center line of the Milky Way, and their spectra show great activity and high temperatures.

The gaseous nebulae and temporary stars show a marked preference also for the Milky Way.

Such preferences as these indicate strongly if they do not establish that their spectral conditions are due in some way to conditions existing in the Milky Way—external to the stars themselves. These facts and the behavior of the temporary stars which successively pass through the B, O and nebular conditions led me some years ago to propose the hypothesis that these spectral types resulted from the cosmical matter which is known to exist in the Milky Way in large quantities. Under such conditions any stars would sweep up such matter as a result of gravitation and increase the temperatures of their surfaces, the amount of increase depending upon the amount of matter swept up. This hypothesis is based wholly upon well-established facts and physical laws and is entirely logical and extremely simple. It is not contradicted by any known fact and fits in well with the general hypothesis of Lockyer.

Recent investigations tend still further to confirm it by explaining the large radial velocities of the O type stars and planetary nebulae as motions of expansion and contraction of their surface layers and not wholly motions of these bodies as a whole. It had been noted previously that the large gaseous nebulae had very small velocities and that the velocities of the stars increased gradually from B to M types. From this it was inferred that the velocities of the stars increased with age, but left the O type stars and the planetary nebulae as anomalies. If these large velocities are confirmed as expansions and contractions all now fall into a regular progression in velocity as well as spectral type and temperature, whichever direction is assumed for the changes.

Until comparatively recently all nebulous-looking objects had been classed together, although differences of form and color had been noted which led to the separation of the so-called "white" nebulae into a subclass which afterward proved to be largely spirals. When radial velocities of the nebulae were obtained by means of the spectrograph it was soon noted that these spiral nebulae had on the average high velocities, about fifty times the average velocities of the stars and other nebulae, and that with few exceptions they are of *recession*.

This at once placed them in a unique position and opened up new problems as to their origin and relationship to the stars and other bodies of our stellar system.

Previous investigations had shown them to be composed, in many cases at least, of thousands of stars, which in connection with their peculiar forms led to the hypothesis that they were separate universes more or less like our own.

Recent investigations, however, at the Observatorio Nacional Argentino have shown relationships of their motions which can be explained only as in some way connected with our system. The brightness of the stars which have been observed in the larger of the spirals is crucial evidence that, although distant, they are nevertheless within the confines

of the galactic system. These relationships are of unusual interest and will be referred to in some detail.

The origin of these spiral nebulae has been even more uncertain than the stars. At least a guess could be made as to the origin of the stars based upon a few well-established facts, as witness the hypotheses of Laplace and Lockyer. But not even a reasonable guess could be made as to the origin of the spiral nebulae, as scarcely a physical fact was known until the spectroscope showed what appears to be a stellar constitution and predominantly high velocities of recession.

These two conditions in connection with their observed forms now permit a certain amount of reasonable speculation.

The spectra of a considerable number of spirals have now been accumulated and are found to be practically those of stars about like our Sun. This fact in connection with the stellar points observed in many of the larger ones seems to establish the fact of a stellar constitution and also that they contain many thousands of times the amount of "matter" in even double stars. This at once separates them from the individual stars and gives them a status as systems of a higher order, but still dependents of the main or galactic system.

The high velocities revealed by the spectroscope also separate the spiral nebulae from the ordinary stars.

These high velocities more than any other feature require an explanation. Recent attempts have been made to explain them on the ground of some form of relativity effect. Such attempts are not well founded, in my opinion, because a consideration of these velocities in detail shows a wide range and that some of them are even *approaching*.

Their reality is still further indicated by relationships to angular distance from the Milky Way, to size and also to their apparent elongations, which have just been discovered in Córdoba.

Because of their high velocities it was suggested several years ago that the "matter" composing the spirals had been originally ejected from the stars of our galactic system and had been gathered together in its distant parts. If this were true these velocities should show some relation to the plane of the Milky Way, those spirals near the poles of this plane having greater radial velocities than those in the direction of the Milky Way. Observations of nearly fifty spirals were available, enough to give confidence in the result. These showed a strong relation of this kind.

During the progress of that investigation it was observed that the smaller spirals had in general larger velocities than the large ones. Also that those turned edgewise had higher velocities than those appearing round or nearly so of the same size. A preliminary examination was made and gave positive results.

Then because of so many relationships mathematical solutions were made to determine them as well as the solar motion which had been ignored, simultaneously. These results fully confirmed the preliminary ones and are given in a paper appearing in the *Anales* of the Sociedad Científica Argentina.

The dependences upon size and inclination appear to be of especial importance.

It was found that the dependence upon size was not linear but inversely as the square root of the apparent diameters. Investigation of actual size by means of Cepheid variables and the brightest stars in eighteen nebulae indicated that the dependence upon size was not upon distance, at least not entirely. If this dependence is wholly upon actual size we have the surprising result that the inverse of the square root of diameter multiplied by the velocity is a constant.

If the constitution of these bodies is the same their masses would vary ap-

proximately as the second power of their diameters, because they are very thin in comparison with their diameters and we would have their masses multiplied by their velocities constant. In other words, their momenta of momentum or total amount of energy would be constant, a condition which has been suggested by some investigators as existing among the ordinary stars from the fact that large and massive stars in general have small velocities and the high velocities are almost invariably found among stars which are believed to be small.

Einstein has formulated the hypothesis that mass multiplied by velocity is constant and limited by the velocity of light: If the dependence of the velocity of the spirals upon size is fully confirmed as a dependence upon mass the possibility is opened up that the resulting equation is not limited to the velocity of light. The consequence of such an equation being true to the limits would be that a mass infinitely large would have no velocity and that an infinitesimally small mass would have an infinite velocity.

In other words, such a condition would lead to the conclusion that matter was only a form of motion.

Such a conclusion would have very far-reaching effects and lead to a drastic revision of some of our ideas, especially as to the so-called elements, the motions of the heavenly bodies and evolutionary processes in the organic world. But it must be emphasized that as yet such thoughts are as speculative as relativity.

The dependence of velocity of a spiral nebula upon the inclination of its plane to the line of sight is in harmony with a dependence upon size, and is in fact a necessary consequence of such a dependence if their mode of formation is found to be what appearances suggest.

The only known method by which such spiral forms can be produced is by the near approach of two bodies as outlined by Chamberlin and Moulton in their planetesimal or spiral hypothesis. The study of many spiral nebulae leaves no doubt that this is the correct explanation of the origin of their forms. It is not necessary to give the entire reasoning. It is sufficient to point out that many cases are known of pairs which appear to be related, and to one in particular, M 51, which shows the disturbing body attached to one of the spiral arms.

Such a dependence of velocity upon inclination as that found in which those whose planes are in the line of sight have larger velocities than those seen at right angles to their planes follows naturally from the near approach and union of two bodies of different velocity but in the same direction, *if their masses are different but their moments of momentum equal or greater than the ordinary effect of gravitation between them.*

This would seem to be in its turn evidence favoring the reality of the dependence upon size and the interpretation placed upon it.

The results enumerated above together with other investigations in hand of the B and A class stars suggest a general hypothesis as to the principal relations and the current evolutionary processes among the stars. No attempt is made to account for the beginning and only an outline can be given. The present state of our knowledge does not warrant anything more.

The course pursued by the stars which seems to satisfy best the observed facts and to be more or less cyclic is that they originate in clouds of cosmical matter as postulated by Lockyer.

By condensation heat is generated which is not radiated away as rapidly as generated, probably due to a blanket of atmosphere, perhaps largely of calcium. The temperature rises until the F, or late A, type is reached where the heavy envelop has been absorbed and radia-

tion exceeds the heat generated by condensation, the surface temperature falls and the spectrum changes in the reverse through G and K types to M.

This is the normal course if undisturbed by additions of matter or energy. (It is difficult to see how any large, sudden *diminution* could take place.)

In the Milky Way regions, however, where cosmical matter is known to be plentiful, encounters with clouds of varying sizes and velocities will cause rises of temperature, some slow, some sudden, and these will be accompanied by changes of spectrum.

If the accretion of energy is slow and of small amount the change of spectrum will also be slow and small and we will have stars of early A type only. A larger accretion will produce the B type of spectrum. Still larger accretion will produce the O type. Sudden encounters with small clouds, at high speeds, will account for the temporary stars, and if these are of sufficient magnitude planetary nebulae will be produced.

If the encounters are with clusters of stars, large irregular nebulae such as those of Orion and Eta Argus will be produced. In all these nebulae are seen the streams and clouds of dark, cosmical matter which have been instrumental in causing the outbursts.

The climax appears to be reached in the production of gaseous nebulosity, after which condensation begins and the spectrum and appearance change as in the large nebula M 8 and in some of the planetaries.

Whether there are still higher stages of activity than the nebular stage is not known. One is inclined to suspect that there are higher stages but that our means of observing are at present inadequate to detect them because of the limit set by our atmosphere to the observation of short waves and perhaps also because the eye is incapable of seeing light of very short and very long waves which are revealed by the spectroscope. Such a possibility receives added weight from the very high velocities of the spirals which require an explanation not as yet forthcoming.

This is essentially the hypothesis of Lockyer modified to include what I conceive to be an offshoot occasioned by conditions existing in the Milky Way which account for the objects with strong preferences for or confined to those regions—the A, B and O type stars, the gaseous nebulae and novae.

Speculation on the beginning of all things and an end or the possibility of a regeneration and cycles offers a fascinating field—but one in which not only an imagination of a very high order is necessary but also an extraordinarily well-balanced judgment to discover the most important facts. A genius could not avoid all the pitfalls in such unknown fields.

And yet real progress is impossible without some plan to work to, even though it may be wrong.

No observed fact raises so strongly the question of infinity of time and space as does that of the high velocities of the spirals. What becomes of this matter or energy? They appear to be beyond gravitational control.

The relativists suggest that these high velocities are not real but a result of curvature of space. But when we are asked to believe that nebulae should be seen twice, on opposite sides of the sky, one seen direct and the other as a result of their light going around the curved way, evidence of a higher order than any given to date is demanded.

But some answer must be found to the question whether such velocities lead to infinity or merely to a regeneration in the outer spaces in the cosmic rays of Millikan, for example, and it is conceivable that the works of the relativists are gropings which will one day discover edible fruit.

I have adverted to the large number of interesting problems now demanding

attention and the impossibility of even mentioning many of them. I will, however, refer very briefly to three which have occupied some attention: (a) periodic phenomena especially noted in the variable stars, (b) the preferential motions discovered by Kapteyn and especially the to-and-fro motions among the stars and (c) the origin of double stars.

Studies of stars varying in light, especially those of short period, showed a tendency for certain types of variation to occur at certain periods and for the amount of variation to be greater at certain periods also.

Preferences for certain periods were also found among the so-called "spectroscopic binaries" whose radial velocities have been found to vary periodically and a further tendency was observed for the lengths of these periods to be arranged in several series which are related by the factor 1/2 or 2. Similar preferences for certain periods, some of them of the same lengths, were also found among the planets and satellites of the solar system, as well as indications of the factor 2.

These relationships require much more study. If fully confirmed the important conclusion is indicated that periodic phenomena, whether of orbital motion or pulsations, are closely related. This in turn would point to some very fundamental underlying condition of matter or energy.

The conclusive evidence which has been discovered that the spiral nebulae belong to our stellar system has suggested a possible explanation for the preferential motions among the stars discovered by Kapteyn and also for their general to-and-fro motions. It is that the stars nearest, perhaps the naked eye stars and somewhat fainter ones, belong to what was once one of these auxiliary systems. It is obvious that the observed stellar motions could be fitted to such a system.

The problem of the origin of double stars has never been settled. Two hypotheses have been advanced: (1) That a single body separated by fission as a result of rotation and elongation. This hypothesis is generally favored and much theoretical work has been done upon it. It is far from convincing, however, as the only known conditions would produce a contrary result. No evidence of weight is forthcoming to produce such accelerations either of rotation or elongation as those demanded. (2) That they have resulted from capture. This theory has in its favor the certainty that near approaches must occur. If these occur in the early stages when stars are believed to be very much extended or perhaps in the cosmical cloud condition, the mechanism is provided for capture.

Evidence favoring the hypothesis of capture has recently been found in the motions of these double stars. If the components originally had motions in all directions, it seems probable that on the average the resulting pairs would have smaller velocities with respect to the galactic or parent system than single stars.

A preliminary investigation of radial velocities and proper motions does in fact indicate smaller motions for double stars than the stars in general, thus appearing to favor a theory of capture.

The foregoing are some only of the very interesting problems which astronomers are trying to solve with respect to the great universe of which we are a part—a very small part only. The Observatorio Nacional Argentino has reached a period in its existence where it is possible to devote a portion of its energies to observations of stars and nebulae in the southern sky to aid in the solutions of some of these problems. A few observations have already been made with the apparatus and time available. With the large reflector now nearing completion it is expected to take a larger share of such work—observations which are badly needed of southern objects.

SOME RECENT CHANGES IN OUR ATTITUDE TOWARDS THE NATURE OF THE PHYSICAL WORLD

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WHENEVER I see a popular or semi-popular book on atoms, electrons, energy or distant universes, an old story comes to my mind written by a Russian humorist and purporting to be an extract from an ancient chronicle. It runs somewhat as follows: One evening a famous philosopher was sitting on the steps of his house, contemplating the stars. A passer-by reverently approached him and said, "Tell me, oh wise man, how many stars are there in the sky?"

"You lown-down ignorant rascal," answered the philosopher angrily, "who can encompass immensity?" And the passer-by, honored by a conversation with the sage, and pleased and satisfied with the answer, went on his way rejoicing.

True, modern writers on the physical world are more polite and evasive in their statements, and perhaps for this reason the readers are not nearly so well satisfied as the ancient passer-by was.

During the past thirty years the progress in physics, chemistry, astrophysics and astronomy has been tremendous, perhaps equal to or exceeding that of several preceding centuries. Human curiosity is also greater than ever, and the man in the street is anxious to learn, without spending much time or effort, what this wonderful progress consists in. It is true that in order to understand in general the present state of knowledge in physics, including not only the phenomena but their interpretation as well, one does not have to be a real expert; in fact, with a few exceptions, an expert usually is a narrow specialist in a particular problem and is not even interested in a synthesis of all that is known. Yet, there is a certain minimum of technical knowledge of the phenomena involved and of the mathematical methods of analysis without which a general story or interpretation of the modern progress in physics is empty and meaningless. It is precisely this minimum of knowledge of the elements that the general reader usually lacks and is unwilling to acquire, making baby talk on the part of even such great writers as Eddington necessary and leaving the reader exactly where he was before, only more humble and discontented with himself and with popular writers.

Some years ago there was a tremendous rise in interest on the part of the general public in Einstein's theory of relativity, an interest which suddenly subsided with a feeling of disappointment and ennui. The man in the street, or at least those who tried to feed him on popularized relativity, learned three things, to wit.: (1) The very special phenomena which had led Einstein to his theory were in themselves not clear to an outsider, and frankly he was not particularly interested in them; (2) the mathematical side of relativity was entirely beyond him; (3) the principle of relativity of space and time did not modify or enlarge his cosmogony, metaphysics or religion; the new abstruse idea remained entirely disconnected from his intellectual and emotional life, and a few scraps taken in were promptly eliminated from his system, like indigestible portions of his meals.

In this article it is impossible even to touch upon the wonderful phenomena and unbelievably delicate measurements of modern physics; it is equally impossible to go into the specific problems of generalization and interpretation of these phenomena and the mathematical means so far mustered for the purpose. Therefore, this discussion must of necessity be couched in quite general terms borrowed, as much as possible, from the every-day experience of my readers.

Perhaps a simile will explain the fundamental nature of the problem with which the greatest physicists are at present concerned. Think of some isolated and fairly primitive agricultural and hunting community in which the political, social and economic relationships have been so well crystallized over a long period of time that no one can even conceive of the possibility of a different organization of society. Let us call this fictitious country Arcadia. Suppose now that because of the new and improved means of transportation and communication, the Arcadians have suddenly found themselves on the verge of quite active intercourse with one of the most civilized countries in the world, say the United States of America. The first ambassadors from Arcadia, upon their arrival in this country, would probably at once ask for the king and the chief priest, would look for large estates cultivated by slaves, vast hunting-grounds, and so forth. Then, after they will have understood the real structure of our society, it will gradually dawn upon them that the political relations at home, far from being universal and divinely ordained, are of very limited application. They will also find that the conditions in this country can not be described in terms of some equivalent institutions at home (even by overworking the adjective "heap-big") simply because there may be no native equivalents for trusts, filibuster, racket, etc. Ultimately, after much study of this country, some of the visiting statesmen may get a fair idea of the evolution of the modern state out of a primitive community, and in this manner mentally place the laws and customs at home in their proper relationship with the principal manifestations of political and economic life in America.

Similarly, a spectroscopist who measures what happens within the atom or an astronomer who deals with the most distant visible celestial objects soon finds that some of the phenomena observed can not be either checked, predicted, coordinated or explained in terms of the classical laws of physics and mechanics. Yet these classical laws, from the days of Galileo and Newton, have been found to be almost entirely adequate for "medium-size" objects, including our every-day life and the solar system. It seems, therefore, that the size of an object studied, or its distance, has something to do with the laws which it obeys; the expression "as immutable as Newton's laws of motion," while still somewhat effective as a figure of speech, can not be used in a strictly scientific treatise any more. Arcadian writers may still use in their essays the expression "as it is impossible to imagine a country without a king and a chief priest," but after their acquaintance with this country this expression at the most would become a weak figure of speech.

So far, no known phenomenon indicates a sudden change in the nature of the laws which it obeys when the size of the constituent parts is allowed to vary gradually. Consequently, we are forced to assume that the change from one set of physical laws to another is gradual. This is equivalent to saying that we really do not know yet the most general laws, but that these unknown laws, *within certain limits,* become almost identical with this or that law deduced

from a limited range of observation. So a sociologist may write a theory of structure of a modern industrial country, and another may write a theory of primitive hunting and agricultural communities, but to formulate one set of universal laws applicable to the whole human evolution (as was attempted by Spencer), from the ape-like state to Tammany Hall, is a stupendous task not yet successfully achieved.

If I use sand merely for ballast, in boxes or bags, the size of grain and the purity of the material are of no particular interest to me; in fact, I do not even think of individual grains and interstices. But if I use very minute quantities of sand, or mix it with cement, detailed properties of individual grains and impurities become of paramount importance. In the light of modern physics, classical scientists handled matter and energy like sand in big closed boxes the contents of which were unknown to them; the laws which they discovered were "bulk" laws; no wonder that these laws do not apply to small amounts of the contents of those boxes. On the other hand, our solar system is like a small grain of sand compared even to our own galaxy, not to speak of remote galaxies. So the time-space relationships deduced from a microscopic study of such a single grain need not necessarily hold true for the whole mountain from which the grain of sand was obtained. This is how Newton's laws of motion appear only as a first approximation in the theory of relativity.

A Greek philosopher taught that earth consisted of earth particles and water of water particles. I suppose many a passer-by went on his way rejoicing after having heard such a gem of wisdom, but I doubt if at the present time a naive theory of this kind would satisfy even a bright primary-grade pupil. The chemistry of a generation ago reduced all existing substances to atoms of some ninety-two elements and their combinations; modern physics has further reduced all these atoms to not more than three constituents, namely, portions of hydrogen and helium atoms, and electrons, in various combinations. The end of the subdivision is not nearly in sight, because each of these constituents has to be endowed with quite a complex structure of its own in order to account for some of the wonderful and manifold physical manifestations known. However, we have already penetrated well into the regions of such small distances that classical laws hold no more.

I can take a small piece of gold and keep on subdividing it by delicate instruments, always obtaining gold of the same density and of the same other physical and chemical properties. It does not make any difference whether gold is continuous or consists of discrete particles; it acts like a continuous solid. When, however, such thin sheets are reached that they become transparent to ordinary light and transmit electrons as through a sieve, one becomes vitally interested in the fine structure of the material. Mathematically speaking, it becomes necessary to assume a discontinuous structure. We now deal with phenomena in the interpretation of which one can not begin with the favorite classical phrase: "Imagine an infinitesimal parallelopiped of dimensions dx, dy, dz." It is like imagining such a parallelopiped in a crate of grapefruit. What you get depends on whether the dimensions of your parallelopiped are of the order of inches or of thousandths of an inch.

A similar situation exists with respect to energy, at least radiant energy. To a classical physicist, light and radiant heat were infinitely subdivisible, and rays could be imagined of any intensity,

down to zero. But for at least a quarter of a century, certain phenomena, such as black-body radiation and the photoelectric effect, defied an explanation, except on the basis of a coarse-grained structure of energy. The same assumption underlies modern spectroscopy and some other branches of physics. Thus was the so-called quantum theory of energy originated which is a counterpart of the atomic and electronic theory of matter. Here again the smallest element, or quantum, of energy (a photon) had to be endowed with various properties before an adequate explanation of even one particular group of phenomena has been reached, and the end of hair splitting is nowhere in sight.

The situation is further complicated by the fact that the minutest known particles of matter, electricity and radiation do not behave in distinctly different manner from each other on all occasions, but sometimes electrons behave like "wavicles," whereas quanta of radiation behave as if they were little chunks of something more material than ether waves. We may have yet to imagine an entity more general than either matter, electricity or radiation, of which entity these three are but particular manifestations. Twenty factory watches differ from one hundred similar watches in quantity only, and one watch differs from twenty watches in quantity only. But the elements of a watch, entirely taken apart, differ from a going watch in kind, and can not be described in terms of a going watch. So it seems as though modern physics has reached a stage of watches taken apart, and not only a new terminology but even a new point of view has become indispensable.

Man has an irresistible tendency to associate new things with old. When I meet a new acquaintance, I try to remember him by saying to myself that he looks somewhat like my Uncle John; islands and peninsulas have been named after familiar objects to which they have only a remote resemblance. Engineering terminology is full of expressions like wing nuts, choke coils, etc., borrowed from common life. Probably our Arcadians, after their return to their native country, would describe our president as a benevolent king, skyscrapers as big huts, and the censor of foreign books in the customs service as the chief priest sent from heaven. It will take them many years to change their point of view and to devise a terminology adequate to describe this country in independent terms. Similarly, modern physicists started at first to interpret intra-atomic phenomena in a macrocosmo-morphic way. An atom emits waves of radiation, so that something must be jerking within it. The nearest approach to such a restlessly moving aggregate in the big world is the solar system. So the physicists evolved a central nucleus within the atom and a number of electrons revolving around it like planets. Difficulties arose with this interpretation, but they bravely struggled on, adding attribute upon attribute, and special "laws" galore, to make the theoretically predicted results check with experimental data, at least to the right order of magnitude.

Finally, the whole planetary structure of the atom became too complex for a mathematical treatment, or even as a picture, and the special "laws" appended to the picture were in a glaring contradiction with the big world of actual experience. The picture of the atom became a hybrid between some elements taken from the macrocosm and others tentatively added as working hypotheses. As soon as the faith in the possibility of constructing the microcosm entirely out of the elements of the macrocosm had been shaken, a few bold spirits undertook the task of wiping out

the whole clumsy structure and began to paint odd futuristic pictures of the atom, electron, quanta, chemical affinity and other fundamental concepts, without any reference to the big world. Evidently, such pictures by assumption can not contain cogwheels, connecting links, orbits and other crude elements borrowed from every-day experience. Therefore, the new theory in its first steps has become entirely mathematical. We must not talk of definite "things" within the atom, or even of definite physical attributes known only from observations in bulk. Instead we are offered a fundamental property of "something ultra-microscopic," expressed in the form of a new-fangled mathematical function, which, after being integrated over an appreciable quantity of matter or energy, gives results in fair accord with actual measurements. If this function can be successfully applied to a variety of problems, there must be something fundamentally sound in it; the function must therefore express something intrinsically extant in the atomic world, although we can not as yet express it in words, for to do this would be to go back to the picture theory of revolving spherical electrons, jelly-like ether and other childish concepts. The recent reaction in physics from the picture theory to the mathematical-function theory is not only natural, but unavoidable. No matter where man tries to interpret nature, he first assumes the simplest possible relationships from his point of view; an infinite resourcefulness of nature becomes clear to him much later. The earth is at first flat with the sun going around it; then the earth is grudgingly allowed to become spherical; still more grudgingly, ellipticity is admitted. Finally it is agreed that the shape of the earth is that of a geoid, which simply means that the earth looks like itself, has a shape of its own. The new tendency in physics is purely ideological; it is only because of the complexity of the abstract ideas involved that they are represented in the shorthand form of mathematical formulas and new mathematical operations. The great advantage is that later any story that seems plausible can be written, or a picture drawn, around these formulas and operations. Take a simple equation, $ax + b = c$, where x is an unknown quantity. This equation can be made to represent the story of a merchant who bought an unknown number of yards of cloth, of a train which started at an unknown instant from a station, of a man who pumped water at an unknown rate, and what not. In regions unknown a purely formal mathematical approach is the safest.

Another way out of being forced to describe too minutely a phenomenon about whose submicroscopic details and mechanism we know but little is to use the statistical method. I have no idea how long John Smith is going to live, but given sufficient data I could tell what his expectation of life or the probability of his dying within the next five years is, what the average income of men of his age and education is, etc. This information is not going to tell you when John Smith is going to die or what his income actually is, but somehow you will feel that you have obtained some useful and essential data about the man. The statistical method in physics was first applied to perfect gases, about the middle of the nineteenth century, giving rise to the so-called kinetic or dynamical theory of gases. With the statistical method, the mathematical physicist does not attempt to specify the position and the velocity of each of millions of particles of a gas, per cubic centimeter, but only computes the probability of a particle having a velocity or kinetic energy between some two given limits. With a

very large number of particles, this probability becomes identical with the actual number of particles endowed with that velocity or kinetic energy. For example, if the probability of being involved in an automobile accident in a large city, within a month, is one hundredth of a per cent., it simply means that actually one out of every ten thousand in that city figures in an automobile mishap each month.

The achievements of the classical kinetic theory of gases in checking and predicting phenomena quantitatively were so satisfactory that it was only natural to extend the statistical method to new problems, involving not only molecules of a gas, but quanta of radiation and electrons as well. However, the early results were far from satisfying, and a possible way out of the difficulty (not a complete solution as yet) has been found in the realization of the fact that there are different kinds of statistics, that is, different methods of computing a probability. We are gradually approaching the situation in statistical mechanics wherein statistical methods are becoming so flexible that almost any desired "bulk" law could be duplicated by choosing suitable assumptions as to single and compound probabilities of the elementary individual events. Let us hope that we shall not go in this respect as far as we have in politics and expert accountancy, where statistics are sometimes made subservient to the will to believe.

The differences between the probability computations in the old and the new statistics may be reduced to the following three: (*a*) In the classical theory, the amounts of kinetic energy ascribed to various particles varied continuously; in the quantum theory these amounts are assumed to vary in small but finite steps. (*b*) In the classical theory each molecule was supposed to have a distinct individuality, so that interchanging the positions or the velocities of two molecules gave a new distribution or arrangement. In the new statistical mechanics, the molecules, electrons or photons are assumed to be indistinguishable from one another, so that interchanging two elements does not give a new arrangement which would increase the total probability of that particular distribution. (*c*) In the classical theory of gases, the particles and their energies were assumed to be entirely independent of one another, whereas in the new statistics assumptions are made as to the maximum number of elements which can have a specified amount of energy each, so that different groups of particles are forced to occupy different "levels" of energy.

To obtain a general idea of the nature of statistical or probability problems in modern physics, consider the following simple case: There is a group of fifteen compartments or cells, corresponding to five units of energy, in the sense that any particle which is placed in one of these cells becomes thereby endowed with five units of energy. There is also a group of twenty cells corresponding to six units of energy. The total number of available particles to be placed in these cells is forty-five and the total combined energy of the particles is 250 units. What distribution of particles in the cells permits of a maximum number of individual arrangements, on the supposition that the cells are distinct whereas the particles are indistinguishable from one another? In actual problems on equilibrium of particles of gas, an assembly of electrons, or black-body radiation, the number of groups of cells, the number of cells per group and the number of available particles are very large, running into millions. Moreover, other conditions are imposed, for example: (*a*) the total number of photons is

not a constant given quantity as the number of particles is above; (*b*) not more than one particle may occupy a cell; (*c*) the presence of a particle in a cell increases or reduces its "attractiveness" for another particle by a given fraction. In this manner, one obtains the so-called Bose-Einstein and Fermi-Dirac statistics and their later modifications and generalizations.

The distribution which gives the largest number of individual distinguishable arrangements is the most probable distribution and the one about which the actual state of the aggregate fluctuates. Moreover, knowing the probability of various other arrangements, the average state of the aggregate (and consequently the magnitude of fluctuations) can also be determined. As stated above, the new statistical methods are quite flexible and can be modified and generalized as actual need arises. In a sense, they have an element of a picture theory in them, for example, as when it is stated that the presence of a photon in a cell increases the probability of another photon joining it in the same cell. However, the picture remains largely mathematical, without describing the shape of the hooks by means of which one photon attaches itself to another.

Now, even if we interpret all the subatomic entities in a mathematical form incapable of visualization, and even if we do the same with the vast spaces of the universe where our ordinary Euclidean relationships hold no more, this will not do away entirely with the bias of the medium-sized world in which we live. For, after all, even our mathematics has been entirely evolved in this inescapable workaday world of ours. To be strictly logical, we should not even use the addition and multiplication signs in the proposed formulas for the subatomic and ultra-galactic worlds, because these mathematical operations savor of the earthly occupations of barter, walking, measuring fields or counting slaves. But here we are almost reaching the limits of the workings of the human mind, *viz.*, the fundamental categories in which it can reason at all. Not that we have reached the highest concepts that the human mind is capable of; compare crude reasoning of a savage with that of our most advanced analytical scientists and synthetic philosophers. Yet, the progress in the very categories of thinking must of necessity be slow and only possible at large intervals, when a new genius arises among us. The purely formal or experimental progress in science is continuous so long as there are talented and devoted men working on a given problem.

Summarizing, I would express my opinion upon the changing point of view in physics as follows: (1) Within the last thirty years a very rapid progress in the technique of measurements has extended the data of physics to extremely small quantities and the data of astronomy to enormous distances and unimaginably large intervals of time. Moreover, many of these data are correct to a high degree of accuracy. (2) The human mind is never satisfied with a mere accumulation of data and always wants to interpret them in terms of some general laws or relationships. The first and natural step was to extend and to adapt the previously known laws of geometry, physics and astronomy to the newly conquered regions. (3) Since these laws failed in some cases, especially in the intra-atomic world, a picture theory of the microcosm was evolved, patterned somewhat after the solar system. Later it became necessary to add numerous details and special laws to the initially simple picture, and even then it did not agree with many experimental data. (4) As a reaction, the picture theory of the atom has given

place to a mathematical or ideational theory (wave mechanics) in which the unknown inner workings are expressed by newly devised formulas and operations for which no physical picture is offered. The proof of these formulas lies in the results obtained by applying them to measurable quantities of matter or energy. (5) In astronomy, the picture theory step was omitted and the generalized theory of relativity has given us directly new time-space relationships, impossible to be visualized, and strictly mathematical in their formulation and application.

I shall not attempt a prophecy as to whether physics will continue to progress and develop at the present unprecedented rate, or whether the progress will slow down. Even assuming that no additional new ideas of importance are to be evolved by the present-day physicists of the first rank and no new scientist of extraordinary vision and skill is to appear say within the next twenty years, it is difficult to conceive of an appreciable slowing down of research in physics. The brilliant and revolutionary ideas hurled at us within the last ten or fifteen years will be sufficient to keep hundreds of talented workers busy for many years to come applying and further developing them in detail. We should be grateful for what has been so generously revealed to us and see to it that the new knowledge has been put to proper use for the benefit of humanity before expecting more.

PENSIONS FOR SUPERANNUATED EMPLOYEES

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SUPERANNUATED employees both in public employment and in private industry are presenting a problem of considerable interest and importance. My first interest in the problem began about twenty years ago through some actuarial inquiries. This interest was extended through my duties as the actuarial member of the Illinois Pension Laws Commission from 1915 to 1919. Since that time many opportunities have come to me to observe the development and reorganization of pension plans for various groups of employees. As the actuarial adviser of the Chicago Pension Commission in 1926, special opportunities came to me again to study the progress in pension plans for public employees. With these rather interesting experiences as a background, it seems not inappropriate to comment on recent developments and to venture in some respects to forecast the future development of pension plans for groups of persons in a common employment. While my main interest has been on the actuarial and technical phases of the operation of pension systems, I shall have the temerity to deal to a considerable extent with the economic and social aspects of the problem.

It is a simple historical fact that the problem of superannuated employees arose much earlier in the public service than in private industry. In fact, some Continental European countries have had pension plans in force for government employees for more than one hundred and fifty years. England has paid civil service pensions since 1810. The earlier development of pension plans in the public service than in industry seems very natural when we recall that, previous to the present age of large machinery, the representative man in industry usually would own his own business or at least the tools with which he earned his income. The units for business operations were small. Relatively more people owned their own homes than at present. Likewise, relatively more people produced part of their own food and clothing than at present. With the development of industries operating large units, vast numbers of employees are very dependent on current income from employment just as public employees are and were at an even earlier date than employees in industry.

To simplify and clarify my terminology, let me say that, throughout this paper, the expression "public employee" will be used in a broad sense to denote civil service employees, teachers, ministers of the church and such other employees in the educational, religious or governmental service as hold positions with a tenure of office with a degree of permanency not less than that of urban public school teachers. The consequences of abruptly stopping the employee's income under present conditions is likely to involve serious hardship both on the employee and his dependents. It is fairly obvious that the continuance of income even for the most substantial class of employees is ordinarily exposed to four major hazards: Unemployment due to business depression; disability due to sickness or accident; death, leaving dependents; old age dependence.

With respect to the first of these hazards—unemployment—we may say that to avoid part of the distress due to unemployment various preventive measures

are employed. In some countries, there are at present formal provisions of law to relieve such distress. For example, we may cite the National Insurance Act of 1911 of Great Britain and the Canadian Federal Provincial Old Age Pension Act of 1927. With respect to disability due to accident and sickness, we note with interest the progress of group health insurance. With respect to the hazard of death, life insurance in its various forms, including group insurance, is daily becoming more effective in the relief of distress. There remains for our consideration the hazard of old age dependency. Various views are held as to the remedies for old age dependency among employees.

It is simply a fact that a large percentage of employees do not make proper provision for old age. Whether it is reasonably practicable for them to provide for old age by the ordinary methods of thrift and saving under present economic and social conditions seems to be a debatable question. On the one hand, we find those who would put the obligation to save for old age entirely on the individual. On the other hand, we find serious students of the subject who do not think that wage-earners in industry, under existing conditions, can be expected to provide for old age. Similar views are frequently expressed in reference to public employees. In brief, we find at one extreme the man who believes in perpetuating the old order by placing the responsibility entirely on the individual for preventing his own old age dependency. At the other extreme, we find the man who would adopt a scheme of general old age pensions to insure the people against old age dependency. But the adoption of general old age pensions presents so many thorny questions that it looks as if the wise course is to seek the solution of the pension problem in the relationship of employer and employee rather than to adopt a scheme of general old age pensions. That is to say, it seems likely that there is a middle ground somewhere between the two extreme positions which offers the best solution of the problem of superannuation of employees both in industry and in the public service. The golden mean is probably to be found in the cooperation of employer and employee to solve the problem in a business-like manner. Such a point of view would seem to benefit both the employer and the employee. At least in theory—and it is believed that the theory is fairly well realized in practice—pensions for superannuated employees are beneficial to the employer. Among several possible benefits, such as continuity in service and improvement in the spirit of the organization, the main benefit of the pension system is to protect the public service and business from incompetence through the continuance in the service of employees after their periods of efficiency are passed. This point was well brought out in an editorial in *World's Work* of February, 1923:

> Most large employers of labor find a system of pensions essential to the efficiency of their staffs. One of their greatest problems has been the disposition of employees who have outlived their economic usefulness. Even the most mechanical practitioner of "efficiency" recognizes that humanity and gratitude are imponderables that can not be disregarded. The result was that useless workmen and executives were kept at work; not only was their labor a liability, but their presence prevented the promotion of effective men. In this way the pension system became an economic necessity. The time is probably not far distant when every prosperous employer of labor will have adopted some plan providing for the future of its workers. Properly regarded, it is not philanthropy; it is simply business.

The view that sound business practice will lead to the adoption of scientific pension plans in the future is strongly supported by the following statement from Reinard A. Hohaus,[1] assistant

[1] "The Function and Future of Industrial Retirement Plans."

actuary of the Metropolitan Life Insurance Company:

> It is advantageous that the employer regard the problem as a business one, and not as one of altruism, charity or reward. When the employer realizes that he must pay pensions, his business training impels him to find a plan which will, in addition, secure as many by-products as it can, such as reduction in turnover, improvement in morale, etc. He will seek a plan which is systematic and definite and sound, and which assesses the cost to the time and place in which it was incurred.

Turning next to the benefits to the employee, the most direct benefit of a pension system to an employee is that it means the prospect of a life annuity beginning at the end of the period of efficient service in the employment. If the annuity is sure to be received, this means protection against the hazard of old age dependency. A well-constructed pension system may, however, bring some benefits that are not quite so direct. Certain types of contributory pension systems seem to me to be significant factors in the promotion of thrift.

Grant, then, that a well-designed pension system is a benefit to both employer and employee, it naturally follows that the pension problem should be studied by both employer and employee with a view to the inauguration of sound plans that are adapted to both the immediate and future needs of the organization and its employees.

Such studies have been made within the past fifteen years of pension systems for public employees by various state and city pension commissions and by some other agencies. For example, extensive studies of the subject have been made and published in reports by the Commission on Pensions of Massachusetts (1914), by the Commission on Pensions of New York City (1916–19), by the Illinois Pension Laws Commissions (1915–19) and by the Carnegie Foundation for the Advancement of Teaching. Many of the principles and provisions of sound pension plans developed in these reports have been summarized and discussed in a book by Lewis Meriam on "Principles Governing the Retirement of Public Employees" and in one by Paul Studensky on "Teachers' Pension Systems in the United States," both published under the auspices of the Institute for Government Research. It was easy to establish the fact that there are in operation many pension systems for public employees that make promises of pensions with little regard to the financial obligations involved in the promises. The difficult task is to find the remedy for such unfortunate practices. The great majority of the pension systems for public employees are either of the "cash disbursement" type or of a type sometimes called the "pot" type. Under a cash disbursement type, the pensions are paid out of the current revenue from the same sources that provide current wages and salaries. By a "pot" type is meant a plan under which somewhat more revenue is collected from employees and employer than is needed currently to pay pensions in the very early years of operation. The money is kept in a so-called "pot" without any definite actuarial knowledge as to the sufficiency or insufficiency of the amount in the "pot" together with future revenue to carry out the promises of retirement allowances. In short, the employee who is depending on such a system to provide a pension in old age is not unlikely to find very little in the "pot" in that future period when his pension rights mature.

Just a little more than ten years have passed since the writer published a paper on "Recent Developments in Pension Plans for Public Employees" in the *Record* of the American Institute of Actuaries. It was there pointed out that we had witnessed in the five preceding years the adoption of reserve pension systems built on comparatively sound financial bases for state employees and teachers in Massachusetts, for

teachers in New York, Pennsylvania, Vermont and Connecticut. These plans followed closely the recommendations of various pension commissions and other agencies that were studying the pension problem. In the ten years since the publication of that paper the drift toward financially sound plans has continued, and much progress has been made in the further study and adoption of such plans. For example, in the State of Illinois alone, we find five reserve pension systems with more than 20,000 public employees participating in partially contributory plans. We find New Jersey, Ohio and Wisconsin added to the list of states with state-wide reserve pension systems for teachers. Several states, including Virginia, Michigan, Iowa and North Dakota, have well-designed plans under consideration for state-wide systems for teachers. We find reserve systems adopted for various groups of civil service employees. Among these is the system for United States classified civil service employees.

Among the recent studies and reports, special mention should be made of the report of the committee of one hundred on retirement allowances of the National Education Association published in 1926. This excellent report makes it fairly obvious that our leaders in the fields of elementary and secondary public school education are interested in sound pension legislation of the adequate reserve type. The report gives also in very clear form the prevailing opinion with respect to controversial points.

Turning next to the industrial field, we note that the industrial pension systems have been studied in recent years by various agencies, and there is good evidence that some employers are vitally interested in the study of this problem. In 1922, a book entitled "A Critical Review of Industrial Pension Systems" was published by Luther Conant, Jr. In an appendix to this book there is presented a brief outline of the provisions of each of the pension systems of ninety-six industrial establishments. The book presents, as implied in the title, an analysis of the significant characteristics and underlying principles of sound pension plans for industrial employees. In 1925, the National Industrial Conference Board published an analysis of 248 different retirement systems operated by 245 different establishments. More recently the Industrial Relations Counselors, Incorporated, have been conducting an investigation of company pension plans in the United States and Canada. A summary of some of the results of this investigation, published in *American Labor Legislation Review* for March, 1929, by Murray W. Latimer, indicates that 466 pension systems have been found in operation, of which 338 are of a formal type while 128 are of an informal character. These 466 systems examined by the Industrial Relations Counselors, Incorporated, were operated by companies employing in the neighborhood of four million workers.

The great majority of the industrial pension systems now in operation are of the cash disbursement type. The employer pays the pension out of current operating expense, making no provision for meeting future obligations. This method has the advantage of simplicity, but it does not stand critical analysis. The pension is based on the tacit assumption that it is a gratuity, and, in the case of some systems, the employer may modify or discontinue the plan at his discretion. As a result of studying various plans in the future as a business problem, it is my prediction that the drift will be away from the cash disbursement plan towards a fundamentally different type of plan. The cash disbursement systems will be replaced for good cause. The "pot" plans will be replaced for equally good, and perhaps for still better reasons. What,

then, will be the essential characteristics of the pension systems of the future for both public and industrial employees?

There is some danger of clouding the issue by bringing into the picture several factors besides old age inefficiency that are very naturally suggested as welfare measures that might be added as sort of riders to the pension plan. This remark is not meant as a criticism of plans that have certain riders. The riders may involve widows' benefits, children's benefits, sickness and accident benefits, and may serve a useful purpose. But my purpose in the present discussion is to exclude all factors except those which pertain to the problem of old age inefficiency in the future of any employment. With this limitation, it seems that the following will be the chief features of future pension plans.

(1) At the date an employee enters upon his pension a sum actuarially equivalent to the benefit will be on deposit in an organization practically as permanent as a legal reserve life insurance company. Such deposits will ordinarily be made possible by the accumulation of deposits over a period of years as nearly concurrent as practicable with the accrual of the liability to pay the pension.

(2) The employee will have a legal claim to the pension, subject to his meeting the prescribed conditions, such as requirements pertaining to age, service and contributions.

(3) The amount of the pension will be fixed with due regard to the variations in standards and habits of life which exist among employees of different earnings, and with due regard to length of service.

(4) The retirement annuity will be granted only on the attainment of an age at which the period of efficiency is very likely to be passing, and retirement will be compulsory after a certain later age, say seventy, except by special action initiated by the employer with the approval of the employee.

(5) The equity of the employee in his pension expectations will be recognized when he withdraws from the employment to the extent to which his salary has been reduced because of the pension prospect.

(6) The operation of the pension system will be under the effective supervision of the State Insurance Department.

With the forecast of the essential features of the future pension plans thus stated somewhat dogmatically, some discussion seems appropriate. The first essential feature relates to the scheme of financing the future plans on a reserve basis. It is predicted that they will be financed on the fundamental principle that at the date of retirement the actuarial equivalent of the benefit will be deposited on behalf of the retiring employee in a fund administered by an organization whose permanency is substantially equivalent to that of a legal reserve life insurance company. To make the operations under this fundamental principle practicable and effective, it will ordinarily be desirable for the employer and employee to deposit in the pension fund currently, during a considerable number of years prior to retirement, equal amounts or amounts that bear a prescribed ratio to each other. These deposits or contributions which the employee makes through deductions from salary and which the employer makes through an addition to compensation will be accumulated at compound interest.

While I thus believe the drift in future pension plans will be in the direction of plans involving joint contributions by employer and employee over a long period of employment, it seems not unlikely in some cases that the period of making contributions should not cover the whole period of employ-

ment and that there may even be cases in which the practical advantages of a non-contributory system outweigh the theoretical advantages of the contributory system, but in every case that has come to my attention it is essential that the plans be so constructed that the actuarial equivalent of the benefit be on hand at the date of retirement. To illustrate from a concrete case, the writer recently examined the operation of the pension system of a large oil company in which the labor turnover during the past ten years was so large that it would almost surely be impracticable to make the scheme contributory for all employees. If it were made contributory for all employees without refunds of contributions upon withdrawal from the employment injustice would be done. On the other hand, if the contributions were refunded upon withdrawal, the administrative expense would probably be so large as to interfere seriously with the practicability of the plan. In such a case, it seems more reasonable for the company to build the proper reserve at retirement on behalf of each employee who is within such a number of years, say fifteen years, of fulfilling the requirements for a pension, that he is not very likely to withdraw from the employment, rather than to subject the operations of the plan to the administrative expense of a contributory system over a long period of time on employees most of whom will withdraw from the employment. Possibly such a system in cases of large turnover may be made contributory over the shorter period, such as the fifteen years preceding retirement age during which the reserve is being deposited, but in this relatively short period the employee would probably be able to contribute only a small per cent. of the total sum required to provide a pension of the desired amount. It seems that the least inference to be drawn from this discussion is that the reserve at retirement age should be built up gradually, in as practical a manner as possible, as the pension rights accrue. On the question of the reserve system, Hohaus, in the paper already cited, expressed the matter aptly in the following form:

> Sound business practice has made it almost mandatory to charge off depreciation for buildings, equipment and other capital assets while in active use and to build up a sinking fund for their replacement. This practice simply provides the funds for the replacement liabilities as they accrue, and not as they mature. This method was not always in effect, but required considerable time, patience and educational work to accomplish its adoption. In like manner, the soundness of a similar practice for the replacement of the superannuated is becoming more generally admitted and, in time, will be in general use. Moreover, I believe that as this reserve principle is recognized, employers will insist on plans, the benefit of which are such that liabilities for them may be definitely determined and so not depend upon the course of such changeable rates as salaries and withdrawals, as those of many present plans do.

The second essential feature stated above is that the employee who has satisfied the requirements for a pension should have a contractual right to the benefit promised. This feature clearly involves an important principle. It seems fairly obvious that the non-contributory pension systems of the "discretionary" type are very far from granting a contractual right. In fact, they very commonly deny explicitly that any such right exists. Some of them state that the plan may be modified or discontinued at the discretion of the employer. There is a reason for this kind of provision. The employers have been feeling their way, and it is rather unreasonable to expect them to guarantee the unsound pension systems which in many cases have probably been copied without careful study. If such a non-contributory system is so well established that employees attach a value to the benefit as part of compensation, it has been fairly well established that, in the large, current compensation will be at a lower level than it would be if the pension system did not exist. In such a situa-

tion the employee clearly has a moral right and should have a contractual right to a pension. When business men study the pension problem more carefully there will be a drift towards making the payments sure. I think it is betraying no confidence for me to say that in the meetings of the Illinois Pension Laws Commission of which Rufus C. Dawes was the member versed in financial affairs, he frequently made remarks to the effect that it was the sureness of the pension rather than its exact amount that seems of first-rate importance and that the pension payments should be made as nearly contractual as possible. Moreover, my experience leads me to say that there exists considerable evidence that employers are as much interested in making payments of pensions contractual as are the employees.

With respect to the proper amount of the pension, it seems fairly obvious that the pension should be of sufficient amount to provide in a reasonable manner for the necessary wants of the beneficiary after the age of efficiency is passed. This amount varies, however, in accord with the standards and habits of life previously followed. If the benefit is too small, there will be a tendency to retain the employee in the active service after his period of efficiency is passed. The salary or wages paid to such an employee is, in a sense, the most expensive kind of a pension. While the amount of pension and salary should be correlated, it seems far from ideal to have the amount based on final salary. In what the writer regards as the ideal scheme of financing a plan, the amount of pension is based on the accumulations from a certain per cent. of salary, set aside throughout a considerable period of service. In the ideal scheme the amount of the pension is simply the actuarial equivalent of such accumulations to the age of retirement.

With respect to age and service requirements for a pension, let me say that some pension systems of the financially unsound variety prescribe merely a period of service such as twenty or twenty-five years as a requirement for a pension. There are others that prescribe both a period of service and a minimum age of retirement. The situation with respect to age and service requirements of different systems is well stated in the 1916 report of the Illinois Pension Laws Commission. That statement portrays an almost haphazard set of provisions which exist in regard to age and service requirements even when the nature of the employment is the same. It seems fairly obvious that some of the greatest abuses of pension systems have their source in the failure to specify a proper age of retirement. When the only requirement is twenty or twenty-five years of service, and the pension consists of a fair per cent. of salary, say in the neighborhood of 50 per cent. of final salary, a considerable number of men enter on pension at ages under fifty. These men are apt to be the most capable men in the employment, as such men may accept the pension and obtain employment elsewhere to advantage. It is entirely foreign to the objects of a sound pension system to enable men to retire on pensions in the prime of life. On the other hand, a standard compulsory age of retirement that insures retirement when it is practically certain that the average employee has passed his period of efficient service is essential. However, instead of a hard and fast compulsory retirement rule, there should be left open the possibility of retaining the employee in the active service by special administrative action initiated by the employer with the approval of the employee. To apply the principle that a pension system is to make practicable and effective the retirement of the employee when his period of efficiency has probably passed and to require his retirement when it is very sure that this period is passed should be the primary objects in the administration of a pension system.

Our next essential feature relates to withdrawal benefits. It seems fairly obvious that when an employee who has contributed to a pension fund is separated from the employment by resignation, dismissal or death an equity must be recognized. In the case of a contributory plan, there is hardly any question that at least the deposits created by deductions from salary should be refunded. The debatable point is on the question as to whether more than these deposits should be refunded.

So far as the writer has been able to learn, all non-contributory pension plans involve the loss of pension right upon withdrawal from employment without regard to length of service. The question as to whether this procedure is equitable is tied up with the question of the effect of a non-contributory pension system on the general level of wages and salaries. But the view has been fairly well demonstrated[2] that in case, and only in case, a non-contributory pension system has become so well established that the employees regard the prospective pension as definitely assured, the operation of the system of pensions tends to develop a scale of wages and salaries on a somewhat lower level than would prevail in the absence of the pension plan. If this view is correct, the withdrawing employee under certain circumstances does not receive equitable treatment. This was the contention of the civil service employees of England in the agitation which preceded the modification of their pension plans in 1909.

The last essential feature on my list relates to supervision of the operations of pension systems by state departments of insurance. It seems clear, in considering the operations of a pension plan, that both the employer and the participating employee should have the benefit of general supervision and of effective examinations from time to time by the state insurance department. In fact, all the arguments for state supervision of life insurance companies may be applied with equal force to the organizations operating pension funds. The proposed contractual provisions will be of real worth in industrial pensions only when the system is in charge of an organization which will not, because of the failure of the business in which the employee gave long-continued active service, find itself unable to pay pension obligations that have accrued. We have already had some examples of hardship to annuitants of pension systems because of the failure of the business in which the annuitants gave their active service and on whose solvency the annuitants were dependent. A few more such failures will lead to regulatory legislation which in turn will involve state supervision.

Before bringing to a conclusion this discussion of my forecast of the main characteristics of the future pension plans for groups of employees, let me sound a note of warning against the inference that I am predicting that the majority of the pension plans of the United States will have these characteristics in the near future. My prediction is far from this. The progress will probably be slow but rather sure. It usually takes considerable time to educate both an employer and his employees to recognize that a sound and equitable pension plan will be economical, in the long run, in spite of the substantial current contributions to the fund. Moreover, it is likely to take considerable time in any given organization to make the necessary gradual transition to plans with the proposed characteristics. However, when American business men really study this problem carefully, the drift towards pension plans of the adequate reserve, contractual type will almost surely be assured and the movement towards plans whose characteristics we have briefly discussed may be more rapid than might be anticipated.

[2] Conant, "A Critical Analysis of Industrial Pension Plans," p. 97.

IS THE PRESENT AMERICAN IMMIGRATION POLICY SOUND?

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WHAT Lothrop Stoddard has called "a master stroke of constructive legislation" became effective in the United States July 1. Stoddard referred to the national origins plan of immigration restriction which fixes at 153,714 the annual number of immigrants who may enter the United States and provides that 43 per cent. of these must come from Great Britain and North Ireland.

In this essay I propose to answer four questions: What should immigration restriction seek to accomplish? Have previous immigration laws been satisfactory? Is the national origins immigration law "a master stroke" in immigration legislation? What shall America do with respect to immigration?

I

Immigration restriction has two aims: (*a*) to admit during a given period of time no more immigrants than a country can absorb without impairing the economic position of that country's resident population; (*b*) to admit only those racial, national and occupational groups which can be assimilated biologically, socially and economically.

The number of immigrants who can safely be admitted into a country within a year or period of years depends upon the existing relationship between land and natural resources and the number of persons residing in that country.

Obviously it is desirable to attain, in so far as possible, the most productive ratio between population and resources. This ratio will have been attained when, in return for whatever expenditure of effort the people of a country regard as normal and proper, they obtain the largest, permanently practicable per capita product. Professor A. B. Wolfe has called this ratio the *optimum*, and a population of this most efficient size, the *optimum population*. An optimum population would, provided there existed an equitable system of distribution, be characterized by the highest possible standard of living.

Neither a large nor a small population, therefore, is *per se* desirable in any country. So long as an increase in population will increase the per capita product such an increase in population is desirable. So soon as a further increase in population threatens to reduce the per capita product no further increase in population should be permitted. Otherwise the standard of living is bound to fall.

It is absurd to argue that it can not definitely be determined when an optimum population has been reached. True, what constitutes an optimum population changes from time to time because the technique of production and the international economic position of a country change. True, assuming that one can determine what is the optimum population, a government lacks the means of so controlling births and deaths as to achieve this optimum. Nevertheless, it is much preferable to make the optimum population the ideal rather than to cry blindly for either a larger or a smaller population. Indexes of production enable man to determine when the optimum population has been reached in a country. Skilfully disseminated propaganda may tend to increase or decrease that country's birth-rate; the volume of immigration can be completely regulated.

Once the optimum population has been determined for a country it is necessary to measure the trend in natural increase (excess of births over deaths), for only then can it be known whether the population is breeding up to or beyond the optimum. If the births in a country are so far in excess of the deaths that the optimum will soon be reached or exceeded, no immigration should be permitted. If, however, a country's population gives no promise of soon reaching the optimum through natural increase then immigration is desirable. Present-day Great Britain illustrates the former and present-day Argentina the latter case.

II

Having determined the number of immigrants that are needed in a country it is next necessary to select those races, nationalities and occupational groups which are desirable.

A country should admit as immigrants only those racial and subracial stocks which amalgamate satisfactorily with the native population. Satisfactory amalgamation through intermarriage will take place only provided that the spread is not too great between the native and the immigrant racial stocks, and that the native population is willing to intermarry with the immigrant stock.

Clark Wissler, curator of the American Museum of Natural History, summarizes prevalent authentic doctrine on racial intermixture in these words:

> While we have little positive knowledge of what happens when races mix, there are not wanting hints that the result is frequently an illy balanced biological individual. Thus Negro-White, Polynesian-White, Australian-White, etc., are combinations of what are sometimes regarded as disparate anatomical units. Some observations in schools and in the army suggest that such mixtures often result in lowering of mentality. However, satisfactory data on these subjects are not available because the subject has not been sufficiently studied in a scientific manner. So, while the subject has not been more than scratched and there are abroad in the land men shouting vociferously that race counts not at all, that peoples should mix indiscriminately, while others say that mixture always results in undesirables, neither of these views can be regarded as unprejudiced or undogmatic, since there are suggestions here and there that the results of such intermixture are not making for progress. . . . The chaotic state of public opinion on this subject is largely due to the lack of reliable scientific data.

If Wissler's statement is accepted as substantially correct, no white country can afford to admit either brown or black immigrants. This is not to imply that either the black or the brown races are inferior to the whites; it is only to state that neither white-black nor white-brown hybrids are stable and desirable biological types. It is possible but improbable, also, that Chinese and Japanese immigrants ought to be excluded from white countries on racial grounds.

If Wissler's statement is held to be invalid, brown, black and yellow immigrants ought, nevertheless, to be excluded from white countries, for in practically every white country the racial prejudice against brown, black and yellow men is so great that their intermarriage with the white population is practically tabu. Hence, even if desirable biologically their amalgamation with the whites through intermarrige is not permitted to take place. It is possible, however, that in the future existing prejudices against the yellow, brown and black races will disappear in proportion as these races achieve complete national sovereignty. Then, if biologically acceptable, yellow, brown and black men will be received in all countries desiring immigrants.

Whether or not yellow-white intermixtures prove desirable may be cleared up in the near future by a study of yellow-white intermixture in Manchuria, for in parts of that state thousands of marriages have taken place between Chinese and Russian whites, exiled from Russia because of czaristic sympathies.

No white country ought, on racial grounds, to reject white immigrants from any other white country. In the

veins of every white nationality flows the blood of all three white races, Nordic, Alpine and Mediterranean. In no country do we find a people that is pure Nordic or pure Alpine or pure Mediterranean. All white nationalities, whether British, French, German, Italian, American or what not, are composites of all three white races. Hence no white country can logically, on racial grounds, exclude whites of other nationalities. The only proviso that should be made is this: admit only those whites whose physical and mental make-up is as good as, or better than, the average of those living in the immigrant-receiving country.

Countries which receive immigrants should determine carefully what economic classes of immigrants they need. Ostensibly only those should be admitted who can perform occupational tasks for which there is a need. Thus if a country has too many miners and too few farmers it should admit not miners but only persons adapted to farm life. If there exists a dearth of unskilled workers and an excess of skilled workers only those should be admitted who can do unskilled work.

In order that only those immigrants will be admitted who are physically and mentally equal or superior to the average native population comprehensive physical and psychological tests must be administered. Those morally undesirable, such as criminals, other than political, ought not to be admitted, even though they pass other tests.

Social assimilation of immigrants must be fostered if they are to intermarry and amalgamate with the native population. To foster assimilation and amalgamation state, church, school and philanthropic institutions must cooperate.

In summary a sound immigration policy demands that: (1) Only as many immigrants be admitted as is consonant with a statistically determined optimum population; (2) members of races which for any reason are prevented from amalgamating with the resident population should be excluded; (3) only those capable of performing the occupational tasks for which there is a need should be admitted; (4) physical, mental and moral fitness should also be criteria for admission, and rigid tests should be given to determine such fitness; (5) organized effort should be made to foster the racial assimilation of the immigrant.

III

Until the passage of the immigration law of 1924 no federal statute for the regulation of immigration even approximated the requirements listed above. Not until 1876 did the Supreme Court declare that Congress had the power to regulate immigration. In 1882 the first general immigration law and the Chinese Exclusion Act were enacted. The former provided that lunatics, idiots and persons likely to become public charges were to be excluded; an earlier law had excluded prostitutes and alien convicts. Other classes of undesirables were added to the debarred list under acts passed between 1882 and 1917. In 1917 Congress passed a bill providing for a literacy test designed to limit the number of immigrants, but few were excluded, as any moron could pass the test. In 1920 an act approved in 1918 was amended "to exclude and expel from the United States aliens who are members of the anarchistic and similar classes."

In 1921 an emergency measure was passed to stem the influx of millions of Europeans who wished to escape the misery and burdens they inherited from the war. Agitation for the restriction of immigration had been steadily increasing in volume since the disappearance of the frontier in the closing decade of the nineteenth century. The growing labor movement feared a wage decline. Racial purists feared the mongrelization of the American stock, for after 1890 more than one half of the immigrants came from eastern, central

and southeastern Europe and hence differed markedly from the native Americans in racial composition and cultural background. Nationalists, become vocal during the World War, feared for our national solidarity and homogeneity. Consequently when 805,228 immigrants came in 1921 and it was threatened that two millions would come each year despite the literacy test and other frail barriers, a law was passed in 1921 providing that "the number of aliens of any nationality who may be admitted under the immigration laws of the United States in any fiscal year shall be limited to 3 per centum of the number of foreign-born persons of such nationality resident in the United States as determined by the United States census of 1910."

The total admissible under this act was 357,803. Of these 55.2 per cent. were assigned to northwestern Europe; 43.7 per cent. to southern and eastern Europe, and 1.1 per cent. to designated parts of Asia, Africa and Australia. No limit was placed upon the number who might come from North America.

The act of 1921 proved satisfactory in but one respect: it prevented the heavy influx of immigrants who would otherwise have entered the United States. The objections raised were numerous. Principally it was contended that the quotas fixed for the countries of southern and eastern Europe were too large when compared with the number these countries had contributed in the past to make up the American population. That is, English, Dutch, Germans, Scandinavians, Irish and Scotch-Irish had made up practically the entire immigration prior to 1890. Consequently, since the blood of these peoples bulked large in the American stock, it seemed advisable that the majority of immigrants admitted under any quota plan should consist of the peoples mentioned. For these peoples resembled the American stock not only in racial make-up but also in political ideals, social training and economic background. The immigrants from southern and eastern Europe, on the contrary, it was asserted, had different political, social and economic backgrounds and hence could not well be assimilated; further, as they were predominantly Alpine or Mediterranean in racial make-up they could not be satisfactorily amalgamated with the native American population. Finally, it was charged, the southern and eastern European immigrants were poorly educated, had too high a birth-rate, consisted of inferior biological stock, were not amenable to Americanization and therefore threatened to stifle progress by making our population too heterogeneous. The army and other intelligence tests and divers evidence of questionable nature were used to bolster these arguments.

Cognizance of the above arguments was taken in the act of 1924 which provided that "the annual quota of any nationality shall be 2 per centum of the number of foreign-born individuals of such nationality resident in continental United States as determined by the United States census of 1890, but the minimum quota of any nationality shall be 100." The total annual quota was fixed at 164,667, of whom 84.5 per cent. consisted of northwest European stock. The act of 1924 provided further that this quota plan would stand until July 1, 1927, after which date quotas would be based upon national origins.

Neither the act of 1921 nor the act of 1924 can be said to have effected a sound immigration policy. The objections to each of these acts are the same as the non-statistical objections to the national origins plan and will be considered in that connection.

IV

Under the national origins plan the annual quota of immigrants for any

nationality "shall be a number which bears the same ratio to 150,000 as the number of inhabitants in continental United States in 1920 having that national origin bears to the number of inhabitants in continental United States in 1920, but the minimum quota of any nationality shall be 100." In plain language this means, for example, that since in 1920 there were in the United States 89,506,558 persons born in, or descended from persons born in, quota countries and since 39,216,333 or 43.814 per cent. of these were of British or North Irish origin Great Britain and North Ireland may send $.43814 \times 150{,}000 = 65{,}721$ immigrants to the United States each year.

The total number admitted each year is fixed at 153,714 for the quota countries. Of this number 82.7 per cent. are assigned to Great Britain, Ireland, France, Germany, Scandinavia, Switzerland, Austria and Belgium. Practically all the others come from southeastern Europe. No limit is placed upon immigrants from countries in North America.

The objections, statistical and non-statistical, to the national origins plan will be considered in order.

It is statistically impossible to determine that 39,216,333 of the white residents in the United States in 1920 were of British and North Irish extraction. This figure consists of four elements: (*a*) 31,803,000 descendants of the people of British and North Irish origin enumerated in the first census taken in 1790; (*b*) 3,728,700 grandchildren, great-grandchildren, etc., of British and North Irish immigrants who arrived after 1790; (*c*) 2,308,419 children of immigrants from Great Britain and North Ireland, and (*d*) 1,365,314 immigrants born in Great Britain and North Ireland.

Of these four elements only (*c*) and (*d*) are given in the census of 1920. Even then for some countries it is impossible to calculate element (*c*). For example, in the census of 1920 children of parents born in prewar Austria-Hungary gave Austria-Hungary as the birth-place of their parents. To-day Austria-Hungary is broken up into many different parts. How, then, other than arbitrarily, can it be said that so many children of parents born in Austria-Hungary are Czechoslovakian, so many Austrian, so many Hungarian, etc. Not even the use of the reported mother tongues removes this arbitrariness.

The estimate of element (*a*) proves to be a sheer conjecture. It is estimated that in 1920 the descendants of the 3,172,444 whites enumerated in 1790 numbered 41,288,570. This was computed as follows. The census of 1920 showed that of the native whites up to five years in age, 75 per cent. had native parents. It was assumed that the parents of these children were aged thirty to thirty-five in 1920, grandparents sixty to sixty-five, and so on. Now of the natives aged thirty to thirty-five, 76 per cent. had native parents; of those aged sixty to sixty-five, 77 per cent. had native parents. Hence of the native children up to five years of age in 1920, 44 ($75 \times 76 \times 77$) per cent. had native grandparents.

So far, so good. But when one tries to determine how many native Americans had native great and great-great-grandparents one engages in guesswork because the necessary data are lacking. The census of 1890 gives the nativity of parentage of natives aged eighty years or more. These were born prior to 1810 and ought, therefore, it is assumed, to enable one to gauge what part of the population born between 1790 and 1810 had native parents. But too few persons survived in 1890 of those born before 1810; in 1890 of each 1,000 persons enumerated in 1810 there survived only thirty-five; of each 1,000 enumerated in 1800, only four, and of each 1,000 enumerated in 1790 only one fifth of one person. Now one can no more assume that 94 per cent. of each 1,000 had native parents because 94 per cent. of

thirty-five, or four survivors, did than one can assume that a bushel of apples is sound simply because a half dozen apples taken from the bushel are sound. In short, we lack knowledge for the years preceding 1810, and possibly 1820. Yet this knowledge is essential to the method of computation employed. How, then, can it be said that of the native whites enumerated in 1920, 41,288,570 were descended from the 3,172,444 whites enumerated in 1790. This figure is further suspect because in no other part of the world has a population of three millions increased twelvefold in 130 years as a result of births in excess of deaths.

If we can not even say that there were 41,288,570 descendants, how can it be asserted that 77 per cent. of these, or 31,803,000, are of British and North Irish origin? The committee of experts who determined the quotas found that of the original 3,172,444 whites 77 per cent. had names that seemed to be British or North Irish in structure. Ergo, 77 per cent. of the forty-one million descendants are British. Such reasoning is most questionable. How can it be known whether a name is British, German or what? The committee admitted this, in part, for at first they held that about 90 per cent. of the names were British. This figure was reduced following protests and further "research." The names were taken, not from original records, but from a general summary published 120 years after the census of 1790.

Even if it were correct to say that 77 per cent. of the names were British it would not follow that 77 per cent. of the descendants were British, for this would assume that the 23 per cent. non-British increased in the same ratio as the 77 per cent. British. This is doubtful. Different nationalities increase at different rates, and the British rate was possibly the lowest, for the New England and Atlantic states, dominantly British in origin for a long time, had a low rate of increase. Hence 30 or more per cent. of the alleged forty-one million descendants may be non-British.

It is even more difficult to estimate the number of grandchildren, great-grandchildren, etc., of British and North Irish immigrants arriving after 1790. First, no immigration records were kept until 1820; those after 1820 for at least fifty years were incomplete. Second, since many non-British immigrants came to this country in British ships and since persons were classed according to the flag of the ship in which they came, the number of immigrants registered as British is too large; thus Scandinavians coming in British ships were classed as British. Third, since there exist very few data on the natural increase of different national stocks and since what data exist show the British to have had the lowest rate of increase it is impossible to assume an equal rate of increase for all nationalities and by a hidden jugglery of figures to estimate that, in 1920, there were 3,728,700 grandchildren, great-grandchildren, etc., of British and North Irish immigrants arriving after 1790.

We have shown the estimate of persons of British extraction to be arbitrary and impossible of statistical justification. One can do likewise for any other country. If it is impossible to determine what part of our population is of a given national extraction it becomes impossible to calculate quotas under the national origins plan. Actually the quotas were computed four times before adoption, and each time they differed. The final British quota is 23 per cent. lower than the original computation; those for Germany, Poland, Czechoslovakia and Irish Free State are respectively 30, 44, 111 and 114 per cent. higher. Could any critic require a more obvious evidence of the statistical unsoundness of the quotas arrived at?

Because of the arbitrary character of the quotas the Senate twice postponed

making the national origins plan effective. As secretary of commerce, Mr. Hoover joined Secretaries Kellogg and Davis in an implied criticism of the plan in a letter to President Coolidge: "We wish it clear that we neither individually nor collectively are expressing any opinion on the merits or demerits of this system of arriving at the quotas." Mr. Hoover vigorously condemned the plan in his acceptance speech. As president he requested the repeal of the plan, which nevertheless was finally adopted despite bitter opposition in the Senate. Mr. Hoover proclaimed the bill a law only because it was mandatory upon him to do so. The adoption of this plan has offended not only national groups in this country but also so-called Nordic nations whose quotas were greatly reduced.

The quotas under the national origins plan have not even the merit of satisfying those who desire a dominantly Nordic stream of immigration. The quotas for Nordic Scandinavia, Germany and Irish Free State have been reduced 63, 49 and 38 per cent. respectively, whereas the quotas of many non-Nordic countries have been increased. Further, since the British did not fill the earlier and smaller quota it follows that this plan will not increase British immigration. Restriction on the basis of the census of 1890 favored the Nordics more than the present plan.

The national origins plan rests upon the assumption that the peoples admitted under it can better be assimilated into the American population. This assumption is false, however. Not nationality but rather an understanding of American traditions, knowledge of the English language, general education and the ability to perform tasks of which we have need are essential to assimilation into the American population. Yet the national origins plan makes no more provision to test the fitness of the immigrants on these grounds than did the previous acts of 1921 and 1924.

The national origins plan violates the cardinal principle of immigration policy, namely, the ability of the United States to absorb more immigrants. We need no permanent immigrants other than skilled professional men and educators. Our population will increase naturally to between 140 and 175 millions within the next fifty years. Why then admit 153,000 unselected Europeans each year, to say nothing of the thousands of non-quota immigrants from Europe or of the 73,154 Canadians and 59,016 Mexicans who came in 1928 and will continue to come, or of those annually smuggled into this country whom Representative La Guardia estimated at 350,000 for Mexico alone? There is little solace in the fact that the last Mexican revolution temporarily reduced Mexican immigration, or that improved border control has reduced illegal entries.

V

What, then, is the United States to do in order to establish a sound immigration policy? A theoretical solution is simple. Putting this solution into effect is equally simple.

First of all, it is necessary to determine statistically whether or not more immigrants are needed. In view of the persistent unemployment the answer would probably be in the negative so far as concerns those other than very skilled artisans, scientists, educators, artists, etc. The United States is not duty bound, as certain Italian thinkers have argued, to relieve the overpopulation of Europe. When America answered in the negative by passing restriction laws, Italy, according to George Young, joined the League of Nations in the hope of obtaining outlet colonies. European overpopulation is a peculiarly European problem to be solved by Europe. By the same reasoning that led us to restrict European immigration we must also restrict immigration from the countries of North America.

Provided it were decided not to admit

other immigrants than artists, scientists, etc., it would be humanitarian to continue the present practice of admitting dependent relatives of immigrants now living here. Temporary admission could be granted to relieve seasonal labor shortage in Maine and the southwest. Other exceptional cases could be settled amicably.

If it were decided that not over 100,000 immigrants were to be admitted annually from all parts of the world precedence would need to be given to dependent but admissible relatives of resident immigrants and to scientists, educators, artists and similar intellectual workers who desire permanent abode in the United States. The remainder would consist of persons able to perform occupational tasks for which the United States had specific need. Nationality would not be made the basis of admission. Instead admission would be allowed each year to the first 100,000, otherwise desirable, regardless of nationality, who satisfactorily passed specially devised psychological and educational tests. These tests would be administered abroad under the supervision of consular officers. Any one seeking to take such a test would have to pay a fee covering every item of expense involved; applicants would thus be limited and no expense would be incurred by the United States. Once admitted the social assimilation of the admitted quota would be fostered judiciously.

If the annual quota were fixed at 100,000, only white nationalities alone ought to be admitted, black and Oriental intellectuals to be excepted, however. If, on the contrary, admission were to be granted only to scientists, educators and artists no distinction ought to be made as to race, color or nationality.

At present there is but a partial trend in the direction of the above suggestions. Already certain preferences are provided for in the issuance of immigration visas. Efforts are being made to restrict immigration from Mexico and Canada. Demands for seasonal labor will probably be observed. F. S. Fitzpatrick, of the U. S. Chamber of Commerce, in an address at the Williamstown Institute of Politics, suggested that an international commission be set up to regulate and select immigrants from Mexico and other Latin-American countries and to adjust their absorption into American industry. To date, however, the notion of optimum population and of the capacity of the United States to absorb immigrants has not affected immigration legislation.

As yet immigration has not, according to Aleš Hrdlička, curator of the National Museum, brought about any physical deterioration in the United States, nor is it likely to.

Economically, however, immigration must be controlled much more rigidly, and along the lines suggested in this article, in order that the American standard of living will not be depressed and that our economic life will not otherwise be harmed.

VIGNETTES OF HENRY EDWARDS AND JOHN MUIR

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ALWAYS the heart of the confirmed collector of insects throbs with joy when he reads such words as these: "In the small box which you sent me are four species new to my collection, and two of these are new to science." These words appear in a letter written on August 25, 1871, by Henry Edwards to his friend John Muir, from whom he had been regularly receiving entomological specimens.

It is easy to visualize the scene: John Muir, the young Scottish naturalist, student and mountain enthusiast, had taken sanctuary in the Yosemite Valley of California, and filled with adoration for its scenic charms at all seasons of the year hardly could be persuaded to leave the spot. With insatiable curiosity and with marvelous constancy and endurance, he spent all his time in exploration and study of nature in grand, solitary places such as this. The association and the cooperation of a man of such type was a veritable godsend to Henry Edwards who, himself, was not only in many respects a kindred spirit but likewise was a man of remarkable and outstanding attributes. Familiarly known among his San Francisco friends as "Harry" Edwards, he was an actor by vocation, though by avocation he was an entomologist. Working in the latter capacity, he had accumulated what was then regarded as one of the largest private collections of butterflies and beetles in the country. The cooperation of two such men in the collection and study of the insects of the High Sierras naturally would be productive of interesting and worth-while scientific results.

It is not only of more than passing interest, but it is of considerable intrinsic value as well, even to-day, to study vignettes of the careers of these individuals and to collate the rather fragmentary and inadequate facts bearing on their contacts with each other which have come down to us. Then, too, it is not unsafe to assume that there probably are scientists of our own day and generation who could profitably ponder lessons to be derived from the excellent example set by these two scientists—men who cooperated or worked together in a common interest during apparently prolonged periods in absolute harmony and friendliness.

An Englishman by birth, Henry Edwards first saw light at Ross in Herefordshire, on August 27, 1830. Little appears on record concerning his childhood and adolescence. It seems that he studied law for awhile in his young manhood, but without evincing any special aptitude for the legal profession. Presently, a combination of circumstances and fondness for commercial enterprise led him into a London counting-house, where Walter Montgomery and John L. Toole were fellow clerks.

Soon he became greatly interested in amateur acting, in association with Montgomery and others. He developed so much talent along this line that he decided, much against the wishes of his parents, to enter upon a professional theatrical career. He made his first appearance as Rudolf in Byron's "Wonder," and in 1853, at the age of twenty-three, he resigned his position as clerk and sailed for Melbourne, Australia, on

a theatrical engagement. In the years that followed he became well known as an actor, serving engagements with different companies in Australia and elsewhere.

By and by he drifted to Peru and Panama, and in 1867 reached San Francisco. About 1877 he made his first appearance in the east at Boston, and finally in 1879 he reached New York City. In that year he was engaged by the late Lester Wallack as a member of his stock company, and became stage manager of the theater. After the disbandment of the Wallack Company in 1889–90, he again revisited his old home in Australia as a manager for A. M. Palmer's "Little Lord Fauntleroy" organization, returning in 1890 to join Augustin Daly's Company.

During all these years he was constantly connected with the stage, until only a short time before his death, when he was compelled to retire on account of illness. His last appearance was in New York in the part of Sir Oliver in "The School for Scandal." Most of the remaining period of his life was spent in the Catskill Mountains in a vain search for health. He died of heart disease, dropsy and other complications in New York City on June 9, 1891.

One of the most interesting of his popular writings which has come to the writer's attention is entitled "A Mingled Yarn: Sketches on Various Subjects," issued by Putnam in 1883, and comprising 157 pages, 12mo, of short sections bearing such titles as "Three Weeks in Mazatlan," "Bubbles from Bohemia" and "Trifles Light as Air." There are brief articles within these dealing with various subjects as, "Shakespeare," "Edwin Adams," "James Hamilton," "Joseph Maguire," "Mid-summer High Jinks," "Two Balloon Voyages," "Agassiz" and "The Church and the Stage." The following extract from the paper on "Shakespeare" is fairly representative of his literary style:

> He [Shakespeare] is preeminently a naturalist, in the broader sense of the term, not the man of mere technical knowledge, of names and terms, of dry classification, whose brain is filled with genera and species, varieties and races, groups and affinities; but one possessed of that faculty of observation (given to but few) even of the meanest things—a power of discovering their varied uses, and pointing out their rank and value in the great chain of nature. The rocks and woods, the trees and flowers, the rolling seas, the calm and the tempest, the sunbeam and the dewdrop, the tiny insect and the giants of the animal world, are alike to him emblems of creative power, and speak to his receptive soul in the divine language of God.

As an entomologist Mr. Edwards had a world-wide reputation and was considered one of the foremost authorities on some groups in that science. He probably will be best remembered by his work on the Lepidoptera of California and the Pacific coast. His excellent papers contain descriptions of many new and interesting species from that region, one of these being "Studies on North American Ægeriidæ." For many years he was deeply interested in entomological bibliography, and his last important contribution was the well-known "Bibliographical Catalogue of the Described Transformations of North American Lepidoptera," a work on which he spent an almost incredible amount of toil and pains—to be fully appreciated only by those who have attempted work of similar comprehensive and long-continued scope. The magazine *Papilio* was edited by him from 1881 to 1883, inclusive, through volumes one, two and three, after which the work passed into the hands of Mr. E. M. Aaron, of whom Edwards wrote with characteristic appreciation at the time he formally relinquished editorship.

Mr. Edwards had membership in many scientific and other societies. He was for some time vice-president of the California Academy of Sciences; he was a life member of the Brooklyn Entomological Society, a member of the Torrey Botanical Club, the Players' Club of

New York and the Bohemian Club of San Francisco; a corresponding member of the Boston Society of Natural History, the San Francisco Microscopical Society, the San Diego Natural History Society and the Belgium Natural History Society. It is easy to see that it was his scholarship and his intense interest in the scientific questions of his day that led him into affiliations with so many of the learned societies, nor do we find that these were perfunctory only, for he regularly attended the society meetings, wrote papers for them and attained to high place in their councils. He also had a great many entomological friends and maintained an extensive correspondence with them. The writer is much indebted to reminiscences of Dr. William Schaus, of the U. S. National Museum, for little word pictures of much interest regarding Edwards, for Dr. Schaus knew him quite intimately, has preserved letters and personal belongings from Edwards and always refers to his association with his friend with an appreciation that does honor to his own discernment and goodness of heart, for it was primarily the aid and encouragement and inspiration received from Edwards during formative years in young manhood that caused Dr. Schaus first to enter upon professional entomology.

Edwards loved his favorite studies quite as much as he did the stage and brought to both an ardor and freshness contagious and perennial. One of his correspondents, writing about him after his death, emphasizes his unvarying kindness and unfailing help to entomologists who were less learned than himself. "I owe much," said he, "to his help and encouragement and shall miss him sorely, though I never saw his face." And it is said that those qualities which so endeared him to a large circle of friends were indeed conspicuous in that face.

His interest in entomology had dated back to the period of his London residence, where under Mr. Doubleday's auspices he commenced the study and collection of insects and there formed the nucleus of the collection that later grew to proportions far beyond any dreams of his earlier years. He spent much money over a long period of years toward the increase of his collection of insects and devoted most of his leisure hours very happily to this, his favorite study.

It is obvious that his extensive travels afforded him many rare opportunities for collecting and otherwise obtaining a vast lot of material not only for his collection but for study and subsequent use in his writings. At the time of his death his collection consisted of about 250,000 specimens of insects of all orders from many parts of the globe. It contained the types of the greater number of the species he described, about four hundred and fifty in all, except a few which were deposited in museums and other collections. It also contained a number of Grote's types of Noctuidae and Pyralidae and many of Fish's types of Pterophoridae and the types of species proposed by other writers. It likewise contained the unique pair of *Oniticellus californicus* and many other uniques, oddities and rarities of considerable value. A significant paragraph by Dr. Morris K. Jesup regarding this collection appears in the "Annual Report" of the American Museum of Natural History for 1891, on page 12:

> Efforts are being made under the auspices of Mr. A. M. Palmer and others of the dramatic profession and friends of the late Mr. Edwards to secure the widely known "Harry" Edwards collection and library. This collection numbers about 250,000 specimens and about 40,000 different species gathered from various parts of the world. Although consisting chiefly of butterflies and moths and beetles, all orders of insects were represented. On account of the great number of type specimens, this collection is considered by good authorities as one of the best in existence, and is also one of the largest private collections in the world. The library accompanying the collection possesses over 500 volumes and about 1,200 pamphlets.

At the time when the "Annual Report" was issued in the following year (1892) the ambition had become realized and there appears the following triumphant entry on page 10 of that publication:

> This Department has beeu greatly enriched and augmented by the acquisition of the well-known collection gathered by the late Henry Edwards, which was partly purchased by friends of the deceased. The collection consists of about 250,000 specimens of insects from all parts of the globe, and is extremely rich in material from this country.

Some idea of the scope and magnitude of the collection and the place it occupied in the program of the museum activities may be gained from still another brief quotation from the "Annual Report" for 1893, on page 12, as follows:

> The butterflies and moths of the Henry Edwards collection were transferred to cases constructed for their reception and these, as also similar material from the Elliot and Augus collections, are now freely accessible and frequent use is being made of them by students and specialists. Satisfactory progress has been made in the work of cataloguing and numbering the specimens.

William Frederick Badè in his biography of John Muir records in a footnote that his attention had been directed by Mr. Frank E. Watson, in charge of the Lepidoptera section of the American Museum, to the fact that in 1881 the butterfly *Thecla Muiri* was named by Edwards in honor of his friend. Apropos of this, we find that in *Papilio,* volume 6, page 54, 1881, Edwards writes: "I have named this exquisite little species after my friend John Muir, so well known for his researches into the geology of the Sierra Nevada, who has frequently added rare and interesting species to my collection."

Through courtesy of the officials of the American Museum of Natural History in New York, the writer has been permitted to examine the record books, correspondence files and Mr. Edwards' other literary remains now forming part of the permanent collections of that institution. To his disappointment no records were found in this accumulated mass that would throw light on the beginning of the friendship between Edwards and Muir, nor has there been definitely determined the extent of the material obtained nor the exact period during which Muir made collections for him in the Sierras. This seems singularly unfortunate as it would be a matter of considerable interest if at least a little more information bearing on these matters were available to students.

In view of the association of these men and the subsequent deposit in the American Museum of Natural History of the collection over which they had spent so much labor and so many hours of happy comradeship, it seems singularly appropriate that its halls should contain in a place of conspicuous honor the splendid bust of John Muir in marble modeled by Malvina Hoffman. Perhaps his labors with Edwards alone, had there been no greater reason therefor, would have rendered him fully deserving of a worthy place in such an educational institution —probably the most far-reaching in its influence of any of its kind in all the world.

Fortunately, through the researches of Dr. Badè and others, this sketch of Muir's career can be made much clearer and less fragmentary than that of Edwards. It is not an extravagant use of language to say that in many respects Muir was unique; not only was he an extremely stimulating and remarkable man, but it is not trite to say that there was no other quite like him. He possessed through aid of memory, observation and fancy that grace and magic of style for which most writers toil in vain. While his writings at times remind one of Thoreau or Burroughs or some one of the other famous writers who have popularized natural history studies, yet he is always distinctive in his simplicity, his gentleness, his wholesomeness and his

intensely human appeal. Entirely aside from the pleasure derived from his word pictures of natural phenomena and the vernal fragrancy with which they are phrased, there are thousands who have gained from his philosophy of life inspiration for renewed endeavor and have been refreshed and stimulated thereby, so as to be able to take up anew and "carry on" what may be to many of them a daily burden of misfit and drudgery.

The first eleven years of Muir's life were spent at Dunbar, Scotland, where he was born on April 21, 1838. His father, being religious in a most offensive manner, was a dour, morose man, having an amazing rigidity of prejudice and an almost unbelievable austerity and lack of common humanity in dealing with his children, with the result that their little lives were rendered unnecessarily harsh and bitter and loveless. The life of a Scottish peasant's child in that bleak climate in a remote country village afforded only the most limited opportunities for early self-improvement; but there is a less gloomy side to the picture, for fortunately there was a bond of affectionate intimacy between the boy and his mother, whom he later in life characterized as a "representative Scotch woman, quiet, conservative, of pious affectionate character, fond of painting and poetry"—one who wrote poetry in her girlhood. Then, too, there was a maternal grandfather, David Gilrye, who took long walks into the country with his small grandson and lovingly imparted to him much information on natural phenomena that undoubtedly laid the foundations of his life-long interest therein. Fleeting glimpses of his childhood reveal him as a "vivid, auburn-haired lad, with an uncommonly keen and inquiring pair of eyes."

In 1849 the family came to America and located on the frontier in a new settlement near Portage, Wisconsin, where two large farms in succession were bought, cleared and brought under cultivation. In this work the lad bore a proportionate share, driven on in stern discipline by an inexorable father who could see no possible success in life for any one apart from the most intense manual labor on a farm and in care of live-stock. Muir's book entitled "The Story of My Boyhood and Youth" contains some exceedingly vivid, unflattering and effective word pictures of that important formative period of his life, and is an indispensable document to all students of the adolescence of genius.

It should not be a matter of surprise that, just as many another lad has been driven away from home by a father lacking in sympathy for and understanding of him, so young Muir bided his time and in 1860, at first opportunity, made his plunge into the big outside world. In the period between 1860 and 1866, after leaving home, he was engaged in teaching; was for four years a student on a self-supporting basis at the University of Wisconsin; was a wandering free-lance student of botany in various parts of Wisconsin and Iowa, and was making a sojourn in Canada during which he spent some time in Toronto and the sections around Lake Ontario, Niagara Falls and Georgian Bay. In 1866, however, because of loss of his position through a fire in a broom-handle factory where he had been employed, he returned to Wisconsin.

In May of that year we find him proceeding alone on foot from Indianapolis, Indiana, on the afterwards famous "Thousand-mile Walk to the Gulf," a detailed account of which he later wrote in his own inimitable way. The temptation is great to quote lavishly from this, but space limitations are imperative. One can only emphasize that all those who have not yet read the book have ahead of them a distinct literary treat. He proceeded leisurely, study-

ing and collecting botanical and geological specimens, through the states of Kentucky, Tennessee, North Carolina, Georgia and Florida; he had some unique experiences in Savannah and he almost perished during an illness at Cedar Keys, Florida, his survival being due to the care given there by some chance acquaintances, named Hodgson. On recovery he sailed to Havana, later to New York, then presently to Panama and soon afterward to California.

The year 1869 was a very full one for Muir, as it was on March 27 that he first reached San Francisco, an event that marked the beginning of a career that was destined to become epochal for both man and the state, and the contemplation of the far-flung effects of which surely haunt human imagination. There was nothing spectacular about the California beginning, however, for the young naturalist drifted slowly and a bit aimlessly through Oakland, San José, the San Joaquin plain and on to Coulterville in varied occupations, such as the breaking of horses, the running of a ferry-boat, the shearing of sheep. Soon he was herding sheep near Snelling at thirty dollars per month, an occupation from which presently he advanced to that of sheep inspector in the Yosemite country. It was at about this time that he first formed the acquaintance with Professor Carr, of the University of California, and also made his first important excursion into the High Sierras —a modest beginning to a brilliant Yosemite career.

With faithful note-book always at hand and with unwearied toil he was constantly on the lookout for what might be learned; he observed the deposition of the snow upon the rocks and trees, studied the individual crystals with a hand lens, detected the squirrel examining its stores beneath the drift and became intimate even with wild sheep that found shelter and protection near his camp. Fortunately passages culled here and there from letters to his various friends[1] or from his writings furnish clues to or at times give lively word pictures not only of his activities during this period of his life but also of his trends of thought. A few illustrations must suffice:

> I expect to be entirely alone in these mountain walks, and notwithstanding the glorious portion of daily bread which my soul will receive in these fields where only the footprints of God are seen, the gloamin' will be very lonely, but I will cheerfully pay this price of friendship, hunger, and all besides.

And:

> When in the woods, I sit at times for hours, watching birds or squirrels or looking down into the faces of flowers, without suffering any feeling of haste. Yet I am swept onward in a general current that bears on irresistibly. When, therefore, I shall be allowed to float homeward, I dinna, dinna ken, but I hope.

Or:

> I knew that mountain boulders moved in music, so also do lizards, and their written music, printed by their feet, moving so swiftly as to be invisible, cover the hot sands with beauty wherever they go.

Again:

> The very finest, softest, most ethereal purple hue tinges, permeates, covers, glorifies the mountains and the level. How lovely then, how suggestive of the best heaven, how unlike a desert now! While the little garden, the hurrying moths, the opening flowers and the cool evening wind that now begins to flow and lave down the gray slopes above heighten the peacefulness and loveliness of the scene.

His sensitiveness to the touch of beauty and his felicity of description often are manifested:

> The grand priest-like pines held their arms above us in blessing. The wind sang songs of welcome. The cool glaciers and the running crystal fountains were in it. I was no longer on but in the mountains—home again—and my pulses were filled. On and on in white moon-

[1] All previously published passages from Muir's letters are here used by permission of Houghton Mifflin Company and taken from Badè's "Life and Letters of John Muir."

light spangles on the streams, shadows in rock hollows and briery ravines, tree architecture on the sky more divine than ever stars in their spires, leafy mosaic in meadow and bank. Never had the Sierras seemed so inexhaustible —mile on mile onward in the forest through groves old and young, pine tassels overarching and brushing both cheeks at once. The chirping of crickets only deepened the stillness.

Again, he is ever alive to the beauties and novelties of the scene:

Meadows grassed and lilied head-high, spangled river reaches, and currentless pools, cascades countless and untamable in form and whiteness, groves that heaven all the Valley!

He had a vivid appreciation of the natural phenomena around him, and apparently fatigue never came to mar the values of the day:

Here I lay down and thought of the times when the groove in which I rested was being ground away at the bottom of a vast ice-sheet that flowed over all the Sierra like a slow wind —my huge campfire glowed like a sun—a happy brook sang confidingly, and by its side I made my bed of rich, spicy bough, elastic and warm. Upon so luxurious a couch, in such a forest and by such a fire and brook, sleep is gentle and pure. Wild wood sleep is always refreshing; and to those who receive the mountains into their souls, as well as into their sight, living with them is clean and free—sleep is a beautiful death, from which we arise every dawn into a new-created world, to begin new life in a new body.

Here and there a star glinted through the shadowy foliage overhead, and in front I could see a portion of the mighty canyon walls massed in darkness against the sky; making me feel as if at the bottom of the sea. The near soothing hush of the river joined faint broken songs of cascades. I became drowsy and on the incense-like breath of my green pillow, I floated away into sleep.

Or occasionally there are aspects that give something of ideal beauty:

The night comes on full of change, sounds from birds and insects new to me, but the starry sky was clear and came arching over my lowland nest seemingly as bright and familiar with its glorious constellations as when beheld through the thin crisp atmosphere of the mountain tops.

His was a soul of an idealist that could translate the carol of a robin heard in a distant mountain of the High Sierras as saying, "Fear not, for only love is here," and he it was who could say, "A crust by a brookside out on the mountains with God is more than all." He expressed his appreciation of God in nature in language that sometimes reveals extraordinary powers of insight and description, and the style takes on at times a haunting beauty:

While we were there, clouds of every texture and size were held above its flowers and moved about as needed, now increasing, now diminishing, lighter and deeper shadow and full sunshine in small and greater species, side by side as each portion of the great garden required. A shower, too, was guided over some miles that required watering. The streams and the lakes and the rains and the clouds in the hand of God weighed and measured myriads of plants daily coming into life, every leaf receiving its daily bread—the infinite work done in calm effortless omnipotence.

A deeper note is sounded in a letter to still another friend when he says:

We are back to our handful of hasty years half gone, all of course for the best did we but know all of the Creator's plan concerning us. In our higher state of existence we shall have time and intellect for study. Eternity, with perhaps the whole unlimited field of God as our field, should satisfy us, and make us patient and trustful, while we pray with the Psalmist, "So teach us to number our days that we may apply our hearts unto wisdom."

His philosophy of life enabled him to write to his old friend, Mrs. E. S. Carr, concerning certain profound changes that had come into her life:

God will teach you as He has taught me that the dear places and dear souls are but tents of a night; we must move on and leave them, though it cost heart breaks. Not those who cling to you, but those who walk apart, yet ever with you, are your true companions.

In a somewhat like connection it was Badè who said of him: "The course of his bark is directed by other stars than theirs, and he must be free to live by the laws of his own life." For, as Muir says:

I understand perfectly your criticism in the blind pursuit of every scientific pebble, wasting

a life in microscopic examinations of every grain of wheat in a field, but I am not so doing. The history of this vast wonderland is scarcely at all known, and no amount of study in other fields will develop it to the light.

It is only here and there in the correspondence examined that statements apear more or less random in character pertaining to the actual details of the collection and shipment of specimens from Muir to Edwards. The extracts therefrom which follow are fairly representative of them.

On August 10, 1871, Muir wrote from Yosemite as follows:

Dear Edwards: I sent you the few flies and bugs which I collected on the Summit Mts. Yesterday by Mr. King, I told him that if it would much delay him to see you he might leave them at Dr. Carr's. Mr. Reilly, a photographer, was in our party; one of the most irritable & unreposable of men & his puny bundlet of frizzling cares prevented me from doing much for you. The butterflies are mostly from the gravelly slopes of Mt. Hoffman; altitude of 9,000 to 10,500. They are quite abundant there but are small, exactly corresponding to the dwarfy flowers upon which they feed. You charged me to look carefully for a white butterfly with red spots. I think that you will find two of this species among those I send. They are from Mt. Hoffman & are not rare, but are very hard to capture. Here is another white fellow that I caught yesterday in the River Canyon below Yosemite. The two small crimson butterflies are from Cathedral Peak, south from Tuolumne Meadows. They are very rapid and restless & appear to like nothing better than to beat about untranquilly in the high winds which constantly sweep the bare bald summits of this whole region. I was surprised at the scarcity of butterflies in the flowery plains about Mono Lake. I don't think that they like so much alkali & volcanic ashes. Still I think it strange that butterflies should be unwilling to dwell where there are such large congregations of contented flowers. I fear that the flies I send are too badly bruised to be of use to you as specimens, but you will at least learn by them that such creatures do dwell upon our high mountains, sometime I shall send you better ones. I captured that large moth here in my hang nest. I don't want to kill any more of that kind because in dying he gasped & throbbed & almost shouted, Murder. John Dennis, who resides at Coulterville, collected some butterflies which he said he would send you. If any of these are rare tell me & I will take pains to catch some more for you. I had some grand glacier lessons among those glorious half in heaven peaks & spent many a rapturous hour with the happy plant children that have home there. I am not working for Hutchings now. Hereafter I mean to make guiding my business & spend all my leisure among Nature's glorious manuscript of mountains.

In a letter to his friend, Mrs. E. S. Carr, August 13, 1871, he says:

I suppose you have seen Mr. King, who kindly carries some butterflies for Mr. Edwards. I thought you would easily see him or let him know that you had his specimens. I collected most of them upon Mount Hoffman, but was so busy in assisting Reilly that I could not do much in butterflies. Hereafter I shall be entirely free.

On February 22, 1873, he wrote to Asa Gray:

Our winter is very glorious. January was a block of solid sun-gold, not of the thin frosty kind, but of a quality that called forth butterflies and tingled the fern coils and filled the noontide with a dreamy hum of insect wings.

Again on March 30, 1873, he wrote to Mrs. Carr:

Oftentimes when I am free in the wilds, I discover some rare beauty in lake or cataract or mountain form, and instantly seek to sketch it with my pencil, but the drawing is always enormously unlike the reality. So also in word sketches of the same beauties that are so living, so loving, so filled with warm God, there is the same infinite shortcoming. The few hard words make but a skeleton, fleshless, heartless, and when you read, "the dead bony words rattle in one's teeth." I sent Harry Edwards the butterflies—did he get them?

Occasionally vague hints were thrown out or catchwords in lightsome caprice were mentioned which were significant of the free and easy comradeship existing between these friends, and make one long to know more details regarding it, as, for example, the joke behind the cryptic reference to Edwards in Muir's letter to his friend, Mrs. Carr, in September, 1874:

While I stood with these dear old friends, we were joined by a lark, and in a few seconds more Harry Edwards came flapping by with spotted wings. Just think of the completeness of that reunion—twenty—Hill Hollow, Hemi-

gonia, Eriogonum, Lark, Butterfly, and I lavish outflows of genuine Twenty Hill Hollow sungold.

Again Muir wrote in graceful rhetoric without conscious art from the Yosemite to Edwards under date of June 6, 1872:

Dear Edwards: Your bundle of butterfly apparatus is received. You are now in constant remembrance, because every flying flower is branded with your name. I shall be among the high gardens in a month or two & will gather you a good big handful of your favorite painted honeysuckers & honeysuckles. I wish you all the deep far-reaching joy you deserve in your dear sunful pursuits.

Muir was not so engrossed in collecting Lepidoptera as to be entirely oblivious to other insect forms, nor were interest or fancy lacking when opportunity offered for making observations upon or of performing experiments with them, as witness his letter to Mrs. Carr in November, 1874:

At length a gray grasshopper rattled and flew up, and the truth flashed upon me that he was the complimentary embroiderer of the lizard. Then followed long careful observation, but I never could see the grasshopper until he jumped, and after he alighted he invariably stood watching me with his legs set ready for another jump in case of danger. Nevertheless I was soon made sure that he was my man, for I found that in jumping he made the shallow pits I had observed at the termination of the pattern I was studying. But no matter how patiently I waited, he wouldn't walk while I was sufficiently near to observe. They are so nearly the color of the sand. I therefore caught one and lifted his wing covers and cut off about half of each wing with my penknife, and carried him to a favorable place in the sand. At first he did nothing but jump and made dimples, but soon became weary and walked in common rhythm with all his six legs, and my interest you may guess while I watched the embroidery—the written music laid down on a beautiful ribbon-like strip behind. I glowed with wild joy as if I had found a new glacier—copied specimens of the precious fabric into my notebook and strode away with my own feet sinking with a dull crounch, crounch, crounch in the hot gray sand, glad to believe that the dark, cloudy vicissitudes of the Oakland period had not dimmed my vision in the least. Surely Mother Nature pitied the poor boy and showed him pictures.

Still another whimsical paragraph, also from a letter, is suggestive of his varying moods:

Yesterday I began to try to cook a mess of bees, but have not yet succeeded in making the ink run sweet. The blessed brownies winna buzz in this temperature, and what can a body do about it? May be ignoramus is the deil that is spoiling—the—the—the—broth—the nectar, and perhaps I ought to go out and gather some more Melissa and thyme and wild sage for the pot.

Especial emphasis has been here placed upon and fuller quotations have been made from the records of the ten years from 1868 to 1879 because it was during that period that Muir made the most extensive as well as the most interesting collections for his friend. Between his excursions in the Yosemite he spent much time either while at camp or at San Francisco in writing for various periodicals including the recently established *Overland Monthly*. Friendly visitors to his domicile during these years or friendships formed by mutual friends or by correspondence included such individuals as Mark Hopkins, Joseph LeConte, Ralph Waldo Emerson, Grace Greenwood, Therese Yelverton, Asa Gray, Mark Twain, Joaquin Miller, Edward Rowland Sill, Ambrose Bierce and Bret Harte. During that decade he also discovered sixty-five residual glaciers in the High Sierras; made an intensive study of the trees of the Pacific Coast, including the *Sequoia gigantea*; made expeditions to Mount Hamilton and Mount Shasta; descended the Sacramento River in a small skiff; made trips down the San Joaquin and Merced Rivers; went with the U. S. Coast and Geodetic Survey into Nevada and Utah and explored the Lake Tahoe vicinity, and in 1879 made his first trip to Alaska and explored some of the upper courses of the Yukon and Mackenzie Rivers. The following winter he was again in San Francisco busily engaged in literary work, and in April, 1880, he married Louie Wanda Strentzel, of Martinez, California, and thereafter for some ten years was engaged in horticultural ac-

tivities at that place, especially in the development of a fruit ranch in the Alhambra Valley near Martinez, inherited by his wife. During this period, however, there were interspersed two more trips to Alaska, one of them being the now famous expedition of the *U. S. S. Corwin*.

The extent of his intimacy with Edwards during all these other activities appears vaguely defined after all these years, though it is evident that in a rather casual way they kept more or less in touch with each other, as witness a letter from Muir to Edwards from Martinez, California, on December 20, 1880:

My dear Harry Edwards, Your kind letter reached me after I had returned from my second visit to Alaska, but I shall most likely go to that far icy country yet once more & shall gladly do what little I can for you now that I have your address. There is a minister residing in the territory at Fort Wrangel, whom I tried to persuade last summer to begin collecting insects. I think you might find it to your interest to write to him on the subject. I told him about you & John LeConte, of Philadelphia. I saw but few butterflies among the many flowers, though as you say all of them must needs be more or less interesting to scientists. I am glad to see that you are still at work in your delightful studies that keep your heart young & that you have not forgotten me. I had hoped to have been east before this time, but my studies drive me like mist & thistledown wheresoever they will. I do hope most devoutly that Emerson will not go away before I see him again. You will doubtless be interested to learn that Ina Coolbuth's poems are to appear in permanent book form ere long. John Carmany is printing them. Ina is still in the Oakland Library though she has long wished to escape from it, as she does not at all like her position there. Thanks for your good wishes as to my marriage all goes well & so naturally that I seem to have been married always. You are sadly missed in San Francisco though I have no doubt you have a much more congenial field where you now are. I shall always be delighted to hear of your happiness. My wife desires to be remembered to you. She speaks of the pleasure she had in seeing you with Modjeska, who is a countrywoman of hers.

After attaining a competency Muir sold the ranch in 1891 and thereafter devoted himself to travel and to a continuation of literary pursuits. In 1884 he was again in the Yosemite with his wife and little daughter, and in 1885 he revisited his boyhood home in Wisconsin. In 1887–1889 he wrote "Picturesque California" and made expeditions to Vancouver, Mount Hood, Mount Rainier, Spokane Falls and the Puget Sound Region, made additional trips into the Yosemite and the High Sierras and wrote extensively for the *Century Magazine*.

He wrote much during those years for newspapers and periodicals urging the formation of national parks, and the establishment of the Yosemite on October 1, 1890, was in great part due to his efforts. Presently in 1890 he was again in Alaska, this time in exploration of Glacier Bay and the now famous Muir Glacier named after him. The following year he was engrossed in work on the Sequoia National Park and the first of the great forest reserves, and on June 4, 1892, he became president of the newly organized Sierra Club, an office which he held for some twenty-two years. In 1892 another visit was made to Wisconsin, a trip that later included the World's Fair at Chicago, New York, West Point, Garrison-on-Hudson and Boston. He then proceeded to England, Scotland, Ireland and other European countries.

The years following the publication in 1894 of his book on "The Mountains of California" were crowded with events; there were more scientific expeditions to the Yosemite and a trip to the Black Hills of South Dakota. There was a trip to Madison, Milwaukee, Indianapolis, Chicago, New York and Boston. In 1897 there followed another Alaska expedition. Sections of the Southern Alleghenies, North Carolina, Tennessee, Georgia and Alabama were studied, and New York, Boston and the Berkshire Hills were revisited. Then in 1899 came the Harriman Alaska Expedition and the publication of two volumes entitled

"Stickeen" and "Our National Parks." These events were followed in 1904 by a scientific expedition to various parts of Europe, Asia, Siberia, Manchuria, Japan, India, Egypt, Ceylon, Australia, New Zealand, the Philippine Islands, Hong Kong and the Hawaiian Islands.

An almost overwhelming sorrow came into his life on August 6, 1905, in the death of his wife. The following year he became engrossed in activities urging the formation of the Petrified Forests of Arizona into a national monument, and still later he became involved in a bitter controversy in connection with the conservation of forest areas in California, known as the Hetch Hetchy Valley Fight, which continued for several years. The volumes from his pen entitled "The Mountains of California" appeared in 1910. Shortly thereafter he embarked upon a trip to South America and spent considerable time in the Amazon country of Brazil, later going on in 1911 to South Africa. His volume on "The Yosemite" appeared in 1912. Presently he was again at Garrison, New York, immersed in writing up his Alaska notes for publication and in composing "The Story of my Boyhood and Youth." In the winter of 1914 he experienced a very severe attack of grippe, this being followed by pneumonia, and he passed away at the age of seventy-six on December 24, 1914.

The book entitled "Travels in Alaska" on which he had bestowed so much time and pains was issued that same year, and posthumous "Letters of a Friend" and "Prose and Letters" appeared in 1915. He was a member of the American Academy of Arts and Letters and a number of other similar associations, and was president of the Sierra and the Alpine Clubs. He received honorary degrees from Harvard, Yale and the University of Wisconsin and California. In addition to being for many years an outstanding champion of the cause of forest preservation and the establishment of national reservations and parks, we have seen that he always manifested deep interest in practically every phase of the physiography and the natural history of the Pacific Coast.

Much has been written of friendship and its felicities, but citations like this from concrete examples in actual biography are of greater worth than many abstractions. Like the flower in the crannied wall, vignettes of this character from human lives, no matter how humble or obscure, if faithfully reproduced, not only can be made interesting and valuable, but can take on a meaning beyond reach of finite language; therefore, no apology need be suggested for dealing with this phase of biography, for the possibilities become endless. As nature at the springtime season comes into new life under the beams of the sun, so human souls are warmed and expanded under the influence of real and genuine friendship. They become more truly conscious of the powers treasured up within. Admirable qualities in another do not overwhelm, but, happily, awaken corresponding nobility. The ties created by such associations are enduring, and souls thus stimulated bind themselves together with peculiar affection. After a long association and intimacy of such kind as here has been considered, there was scarcely need of speech to communicate sympathy; the fellow feeling had its own language and its own spirit and permeated an otherwise prosaic message: "In the small box which you sent to me are four species new to my collection, and two of these are new to science." Such is the blessed wealth of many human hearts that they continually run over with affection for their friends—affection that not only brings with it consideration, patience and forbearance for others having like tastes, but presently extends to greater charity for all mankind. In the mutuality of such tastes and interests there is more abundant life and increase in permanent happiness.

A person having the gift of making and keeping friends and who proves worthy of having friends is a millionaire at the treasury of love.

MINUTE ANIMAL PARASITES OF MAN

By Professor ROBERT HEGNER
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FEW people realize what a vast number of minute animals, called protozoa, inhabit the earth. This is largely due to the fact that these organisms are microscopic in size and thus do not come within the experience of any except biologists, and most of these have but a casual acquaintance with members of the group. We are accustomed to think of man as the dominant animal on the surface of the earth to-day, and this is correct when considered on the basis of certain criteria; but, in several respects, the Protozoa are and perhaps always will be dominant—these are in numbers of species and in numbers of individuals belonging to each species. Protozoa are called unicellular organisms because most of them are made up of but a single cell. They are able, however, to perform with this single cell all the fundamental processes characteristic of higher animals that make it possible for them to maintain themselves in their environment and also to maintain their numbers. The latter is accomplished by the process of reproduction, which, in most species, is a comparatively simple division of the parent into two daughter cells; these, after a short period of growth, divide in turn into offspring. The parent thus loses its identity at the time of reproduction and its body is equally divided between its two immediate descendants. Inasmuch as growth is often very rapid and division may occur many times in the course of a single day, the number of offspring that may result from the reproduction of one individual protozoon reaches in a few days an enormous total.

The habitats of protozoa are numerous and varied. All of them require one environmental factor, namely, moisture, since they die immediately if they become dry. Most biologists are content to study the protozoa they find in fresh water or in the sea. Many species and enormous numbers of individuals, however, live in the soil to a depth of several feet, and a still larger group live inside other animals and plants. The latter are usually called parasites, although only a small proportion of them are known to injure their hosts perceptibly. The number of species and number of individuals belonging to the parasitic protozoa may be realized when it is stated that almost every species of animal thus far examined has been found to be parasitized by one or more distinctive species, and that a single animal may contain billions of individuals of a single species. Man is no exception. Human beings have probably been examined for protozoon parasites more diligently than has any other animal. Protozoologists differ slightly with respect to the number of "good" species that occur in man, but the most recent studies indicate that there are about twenty-five. These belong to all the four large groups into which the protozoa are divided: (1) amebae, (2) flagellates, (3) ciliates and (4) sporozoa. Apparently no antagonism exists among these protozoa, and one person may be infected at one time with several blood-inhabiting species and two or three or more intestinal forms.

The ameba that is best known to biologists is *Amoeba proteus,* a species that lives in fresh-water ponds. It is often described as a shapeless mass of protoplasm containing a nucleus. Changes in shape are due to the flowing out of false feet or pseudopodia. Human beings are infected with six different species of amebae; one lives in the

mouth and the other five in the large intestine. The species that lives in the mouth is known as *Endamoeba gingivalis* (Fig. 1a). It lives in the gingival spaces at the base of the teeth and is present in probably 50 per cent. of the general population. Since transmission no doubt takes place during kissing, every one at some time in his life is liable to become infected. The reason that infection is not more wide-spread is no doubt due to individual resistance rather than to freedom from contamination. It is of interest to note that this species, which is transmitted directly by contact, does not include in its life-cycle a cyst stage, such as is characteristic of the amebae of the human intestine which must pass part of their lives outside of the body of their host. Some years ago *Endamoeba gingivalis* was accused of causing pyorrhea alveolaris, but more recent studies indicate that it is really harmless.

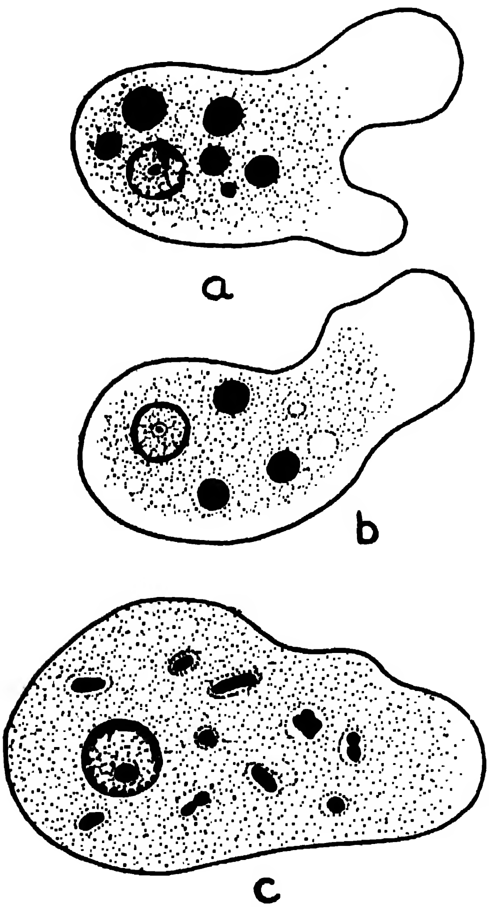

FIG. 1

A large proportion of human beings also harbor in their mouths a flagellate known as *Trichomonas buccalis.* This species is likewise transmitted by contact and appears to be harmless. Human beings with diseased mouths are, however, more frequently infected than those with healthy mouths, and there is still a possibility that this flagellate is a pathogenic organism.

No protozoa are known to inhabit the human stomach, but about 10 per cent. of the general population are known to be infected by a flagellate, *Giardia lamblia* (Fig. 2a), that lives in the anterior portion of the small intestine. This peculiar protozoon is bilaterally symmetrical, and its two nuclei resemble eyes. Its most prominent feature is a sucking disk which occupies a large part of the ventral surface and enables it to attach itself to the epithelial cells of the intestinal wall. This sucking disk enables this species to maintain its position in the small intestine against the force of peristalsis which tends to carry it downward. Physicians have reported large numbers of giardias in patients suffering from diarrhea in whom no other cause of this intestinal disturbance could be found, and hence believe that the flagellates are responsible for the condition observed. Whether or not such a disease as flagellate diarrhea really exists, however, is still in doubt.

Another inhabitant of the small intestine of man is a sporozoon, *Isospora hominis,* that has been reported from various parts of the world but seems to be rare wherever it occurs. This species penetrates the cells of the intestinal wall where it undergoes growth and both asexual and sexual reproduction. The

final results of the latter are resistant bodies called oocysts which pass out with the excretory products. This human sporozoon is known only in the oocyst stage and we must construct its life-cycle within the body on the basis of our knowledge of the life-cycles of similar species in cats and dogs. *Isospora hominis* is pathogenic and is responsible for a diarrheic condition but is not an ordinary cause of death and is too rare to be of much importance.

The large intestine of man seems like a little world created for protozoan parasites to live in. Here occur five species of amebae, four species of flagellates and one ciliate. The amebae vary with respect to the frequency of their presence and to their relations to their host. The only species known with certainty to be pathogenic is *Endameba histolytica* (Fig. 1b). This species invades the intestinal wall where it produces ulcers. Dysentery, often fatal, results. About 10 per cent. of mankind are infected, but in most cases the human body seems able to repair the damage as rapidly as it is done and are therefore said to be in the "carrier" condition, a carrier being a person who is infected and passing infective stages but does not exhibit symptoms. Amebae that are at work in the intestinal wall may enter capillaries and be carried in the blood stream to other parts of the body. Where conditions are favorable, infections are set up. Thus in a large proportion of cases of amebic dysentery, liver abscesses due to the amebae are also present. Abscesses in the lungs, spleen, brain, etc., may also be the result of amebic activities. Fortunately, there are effective methods of treating amebiasis, such drugs as emetin, yatren and stovarsol having been developed for this purpose.

The other four species of amebae inhabiting the human large intestine are considered to be harmless. Two of these species are of very frequent occurrence: *Endamoeba coli* (Fig. 1c) is present, on the average, in about 50 per cent. and *Endolimax nana* in about 25 per cent. of the general population. The other species, *Iodamoeba williamsi* and *Dientamoeba fragilis,* are comparatively rare.

Two species of flagellates that live in the large intestine are rather common but the other two species are seldom encountered. *Trichomonas hominis* (Fig. 2b) appears to vary greatly in its incidence in various parts of the world. In tropical America the writer found 20 per cent. of the inhabitants to be in-

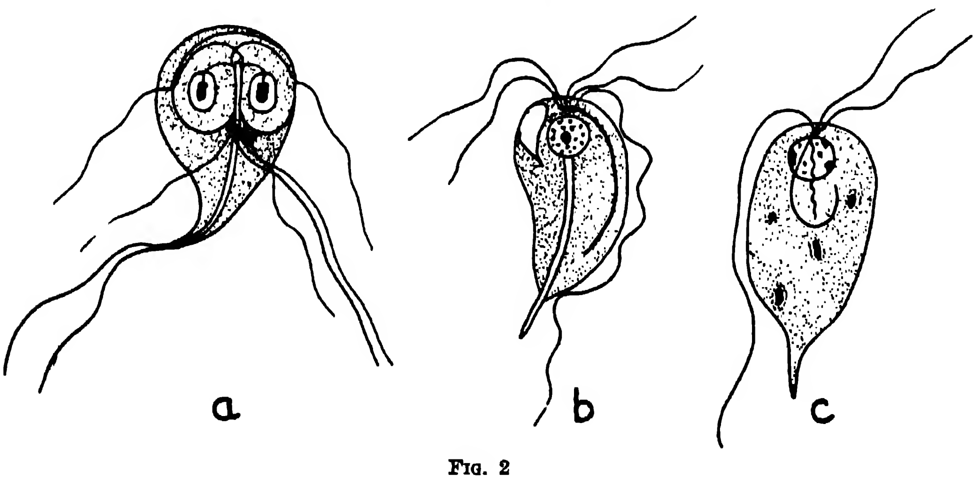

FIG. 2

fected, whereas in other localities less than 5 per cent. have recognizable infections. This may be due to differences in diet and in sanitary conditions. *Chilomastix mesnili* (Fig. 2c) is likewise a common intestinal flagellate, being present in about 10 per cent. of the general population. Both these species have, as in the case of *Giardia lamblia,* been accused of causing flagellate diarrhea but have not yet been found guilty beyond reasonable doubt. The rare flagellates of the large intestine are *Tricercomonas intestinalis* and *Embadomonas intestinalis.*

A single species of ciliate, *Balantidium coli,* rarely occurs in the large bowel. It resembles very closely in size and structure the common *Paramecium caudatum* of fresh water. Most persons who are infected with this protozoon seem not to be injured by it, but occasionally the organisms penetrate the intestinal wall and bring about the formation of ulcers and produce dysenteric symptoms. No specific treatment is known, although some success seems to have been obtained by regulating the diet and administering the drug named stovarsol.

In the group with the intestinal protozoa is usually included a flagellate, *Trichomonas vaginalis,* which occurs in the vagina of a large percentage of women and has been recorded from the urinary tract of a number of men. This species is believed by many physicians to be pathogenic, although it has not been incriminated with certainty.

Besides the fifteen so-called intestinal protozoa described above there are nine blood-inhabiting protozoa and a single species that has been recorded in a few cases from the muscle tissue of man. This muscle parasite is a sporozoon of the genus *Sarcocystis.* How it reaches human muscle is unknown, but it has been suggested that it is a normal parasite of some lower animal that rarely finds its way into human beings where it occupies a "blind alley" from which it is never able to escape.

The blood-inhabiting protozoa of man are among the most important of all disease-producing organisms. The three species of malaria parasites occur throughout a large part of the tropical and subtropical regions of the earth. The three species of trypanosomes are restricted to certain parts of tropical Africa and tropical America, and the three species of leishmanias are prevalent in Asia and the Mediterranean region and also in parts of tropical America. Malaria (Fig. 3a) has been for many years and still is the most important of all tropical diseases. Theoretically it is easy to control because we know that it is transmitted by the females of certain species of mosquitoes, and we possess in quinin and plasmochin two drugs that are very effective in destroying the organism in the human body. In such places as Havana and the Panama Canal Zone it was found possible to eradicate malaria because there were no restrictions as regards authority, methods and funds, and good men were engaged to do the work. The

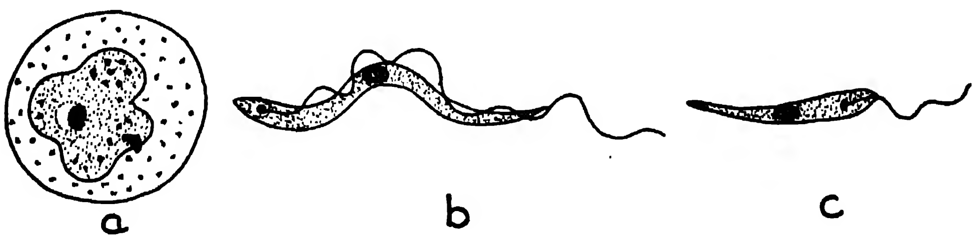

FIG. 3

inhabitants of many areas, especially those that are thinly populated, are, however, too poor to pay for properly carried out control measures. Malarial relapses complicate the situation, since usually patients are not actually cured by the drugs administered to them but retain enough parasites in their bodies to bring about a relapse when the resistance of the host becomes lowered. This often occurs in the spring just when mosquitoes become active, and the transmitters of the disease are thus provided with sources of infection.

Trypanosomes (Fig. 3b) are responsible for African sleeping sickness and Chagas' disease in South America. They do not live within the red corpuscles, as do the malarial parasites, but in the blood plasma. Large parts of Africa are uninhabitable because of the presence of trypanosomes. Wild game animals, such as antelope, serve as reservoirs of the trypanosomes of man in Africa from which the transmitting agents, the tsetse flies, may acquire their infections. Drugs such as Bayer 205, tryparsamide and Pasteur 309 are useful in the treatment of African sleeping sickness if administered in the earlier stages of the disease. Chagas' disease is transmitted by kissing-bugs of the genus *Triatoma* that live in the crevices of the mud huts of the natives in certain parts of South America. The armadillo has been found to serve as a reservoir for the species of trypanosome that causes this disease.

The leishmanias (Fig. 3c) cause kala-azar and oriental sore in certain regions of Asia and the Mediterranean region and uta in tropical America. The transmission of these diseases has not yet been determined, although the sand-fly probably is the intermediate host of the organism of oriental sore. This disease is of particular interest because one attack gives immunity, and since the sores usually occur on the face and leave scars, children are sometimes inoculated on some other part of the body by their parents so that they may escape disfigurement.

The following table presents a list of the twenty-five species of human protozoa.

PROTOZOA LIVING IN MAN

A. *Intestinal protozoa.*—These appear to be world wide in their distribution. They are located within the body as indicated.

Mouth	Percentage of population infected
1. *Endamoeba gingivalis* (ameba)	50
2. *Trichomonas buccalis* (flagellate)	10–30
Small Intestine	
3. *Giardia lamblia* (flagellate)	10
4. *Isospora hominis* (coccidium)	Rare
Large Intestine	
5. *Endamoeba histolytica* (ameba)	10
6. *Endamoeba coli* (ameba)	50
7. *Endolimax nana* (ameba)	25
8. *Iodamoeba williamsi* (ameba)	10
9. *Dientamoeba fragilis* (ameba)	Rare
10. *Trichomonas hominis* (flagellate)	5–20
11. *Chilomastix mesnili* (flagellate)	10
12. *Embadomonas intestinalis* (flagellate)	Rare
13. *Tricercomonas intestinalis* (flagellate)	Rare
14. *Balantidium coli* (cilate)	Rare
Vagina or Urinary Tract	
15. *Trichomonas vaginalis* (flagellate)	10–50 women

B. *Protozoa of muscle tissue.*—Only one apparently aberrant species is known to occur in man.

16. *Sarcocystis* sp. (sporozoon)	Rare

C. *Blood-inhabiting protozoa.*—These are restricted to certain rather definite areas as indicated.

Red Blood Corpuscles	Geographical Distribution
17. *Plasmodium vivax* (sporozoon) (organism of tertian malaria)	Tropical and subtropical countries
18. *Plasmodium malariae* (sporozoon) (organism of quartan malaria)	Tropical and subtropical countries
19. *Plasmodium falciparum* (sporozoon) (organism of estivo-autumnal malaria)	Tropical and subtropical countries
Blood Plasma	
20. *Trypanosoma gambiense* (flagellate) (organism of Gambian sleeping sickness)	Tropical Africa
21. *Trypanosoma rhodesiense* (flagellate) (organism of Rhodesian sleeping sickness)	Nyasaland, Rhodesia, etc.
22. *Trypanosoma cruzi* (flagellate) (organism of Chagas' disease)	Northern South America
Blood and Body Cells	
23. *Leishmania donovani* (flagellate) (organism of kala-azar)	Asia and Mediterranean regions
24. *Leishmania tropica* (flagellate) (organism of oriental sore)	Asia and Mediterranean regions
25. *Leishmania brasiliensis* (flagellate) (organism of uta)	South and Central America

The protozoa of monkeys as well as of men have been carefully studied. The results are of considerable biological interest since in most cases it has been impossible to distinguish the parasitic protozoa of man from those of monkeys. The monkey protozoa have been given distinct scientific names, but the foremost protozoologists at the present time are unable to distinguish them from the protozoa of man. Original observations by the writer and a review of the literature indicate that twenty of the protozoa of man also occur in monkeys.[1] The five species that have not been recorded from monkeys are as follows: the three species of *Leishmania;* the coccidium, *Isospora hominis,* and the sporozoon, *Sarcocystis.* It is interesting to note that *Isospora* and *Sarcocystis* are very rare in man—a fact which suggests that they may eventually be discovered in monkeys. There is no obvious explanation of the absence of the leishmanias in monkeys since it is possible to infect monkeys with them under laboratory conditions. Protozoa belonging to two genera and four species have been found in monkeys but not in man; these are the intestinal ciliates *Troglodytella abrassati, T. a. acuminata* and *T. gorillae,* and the blood-inhabiting sporozoon, *Babesia pitheci.*

Other lower animals, such as cats, dogs, rats, cattle, birds, lizards, frogs, etc., are parasitized by both intestinal and blood-inhabiting protozoa, many of which belong to the same genera as those in man; but, almost without exception, it is possible for one familiar with these organisms to distinguish them morphologically as specially different from human protozoa. For example, the following species belonging to the same genera occur in rats and man:

Rat	Man
Giardia muris	*Giardia lamblia*
Trichomonas muris	*Trichomonas hominis*
Endamoeba muris	*Endamoeba histolytica*
Trypanosoma lewisi	*Trypanosoma gambiense*

A protozoologist can identify these species from these two hosts on the basis of difference in structure without knowing from which host they were obtained.

These observations have an important bearing on the theory of organic evolu-

[1] Robert W. Hegner and William H. Taliaferro, "Human Protozoology," 1924; C. M. Wenyon, "Protozoology," 1924; current literature referred to in *Quarterly Cumulative Index Medicus.*

tion, since it has been found that animals that are closely related are infected with similar parasites and the closer their kinship the more nearly alike are their parasites. The remarkable situation noted above with respect to the protozoan parasites of monkeys and man indicate that a very close relationship exists between these types of hosts. It seems very probable that the protozoa that are now found in man and monkey are direct descendants of protozoa that lived in the ancestors of these hosts, and that man and monkey had the same common ancestry. Thus the study of protozoan parasites has furnished us with another important type of evidence in favor of the organic evolution of man from a monkey-like ancestor.

To summarize, human beings are parasitized by about twenty-five different species of protozoa. Some of these, the intestinal protozoa, appear to be world wide in their distribution; others, the blood-inhabiting protozoa, are restricted to certain geographical areas. Fortunately, most of these parasites are either harmless, of very little clinical importance or not of frequent occurrence. The most dangerous species are the malarial parasites which occur generally throughout tropical and subtropical countries and are the cause of the most important of all tropical diseases, the trypanosomes that are responsible for sleeping sickness in certain parts of Africa and of Chagas' disease in South America, the leishmanias that cause kala-azar and oriental sore in parts of Asia and the Mediterranean region and uta in South and Central America, and *Endamoeba histolytica* which occurs throughout the world but brings about amebic dysentery usually only in the tropics. Drugs have been discovered that are effective against most of these parasites, and infected persons can be cured or at least relieved of their symptoms if treatment is begun in the early stages of the disease. The high percentage of the general population infected with intestinal protozoa indicates that our food and drink must be highly contaminated and that our sanitation is not as effective as it should be. A comparison of the protozoa living in monkeys and man reveals the fact that twenty of the twenty-five species recorded from man also occur in monkeys. This indicates a close genetic relationship between monkeys and man and suggests that these protozoa have accompanied monkeys and man in their evolution from a common ancestor.

RECENT STUDIES OF HAIR STRUCTURE RELATIONSHIPS

By Professor LEON AUGUSTUS HAUSMAN

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HAIR, characteristic of the *Mammalia*, and found in no other animal group, present in all species though but sparsely developed in some, occurring in all gradations of development from a mat of fine soft fur to a panoply of coarse heavy spines, is a product of the outermost layer of the skin, the epidermis, and no matter how different it may appear in its apparent forms is structurally a remarkably homogeneous animal tissue. Each hair shaft arises from the proliferation of the cells of the bulbous upward growth in the base of a flask-shaped depression in this epidermal layer, the bulbous growth being known as the papilla of the hair (Fig. 1, A). The rapid multiplication of the cells upon and around this papilla results in the gradual extrusion of these proliferated cells toward the mouth of the follicle at the level of the epidermis. These cells form both the layers of the root sheath of the hair and the four structural elements of the hair shaft. The hair shaft is now pushed out of the mouth of the follicle, with its four structural elements established. These are (Fig. 1, B): (1) the medulla, or medullary column, made up of variously disposed chambers sometimes separated, sometimes coalesced, and termed popularly the pith of the hair; (2) the cortex, surrounding the medulla, composed of elongated, fusiform, often much shrunken cells (sometimes referred to as hair spindles) fused together into a rigid, almost homogeneous, hyaline, transparent mass; (3)

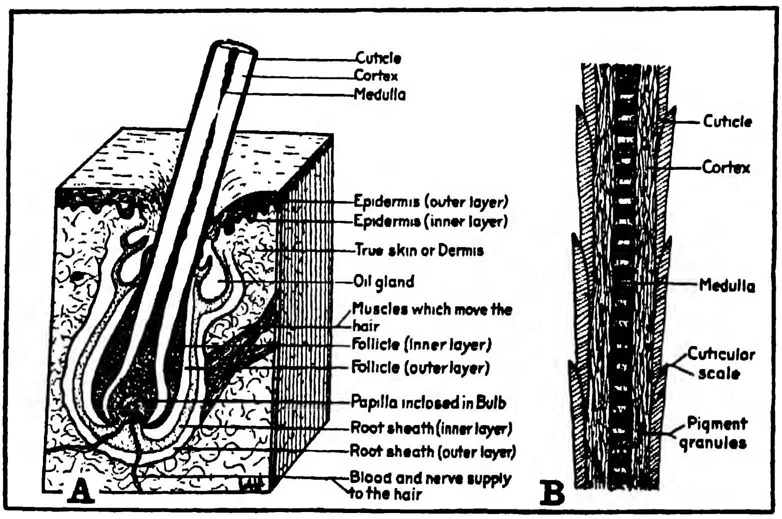


FIG. 1. A DIAGRAMMATIC LONGITUDINAL SECTION

A. THROUGH A MAMMALIAN HAIR OF THE BROKEN-MEDULLA TYPE, AND ITS TISSUES OF ORIGIN AND ATTENDANCE. *B.* A SIMILAR SECTION THROUGH A HAIR-SHAFT OF THE DISCONTINUOUS-MEDULLA TYPE.

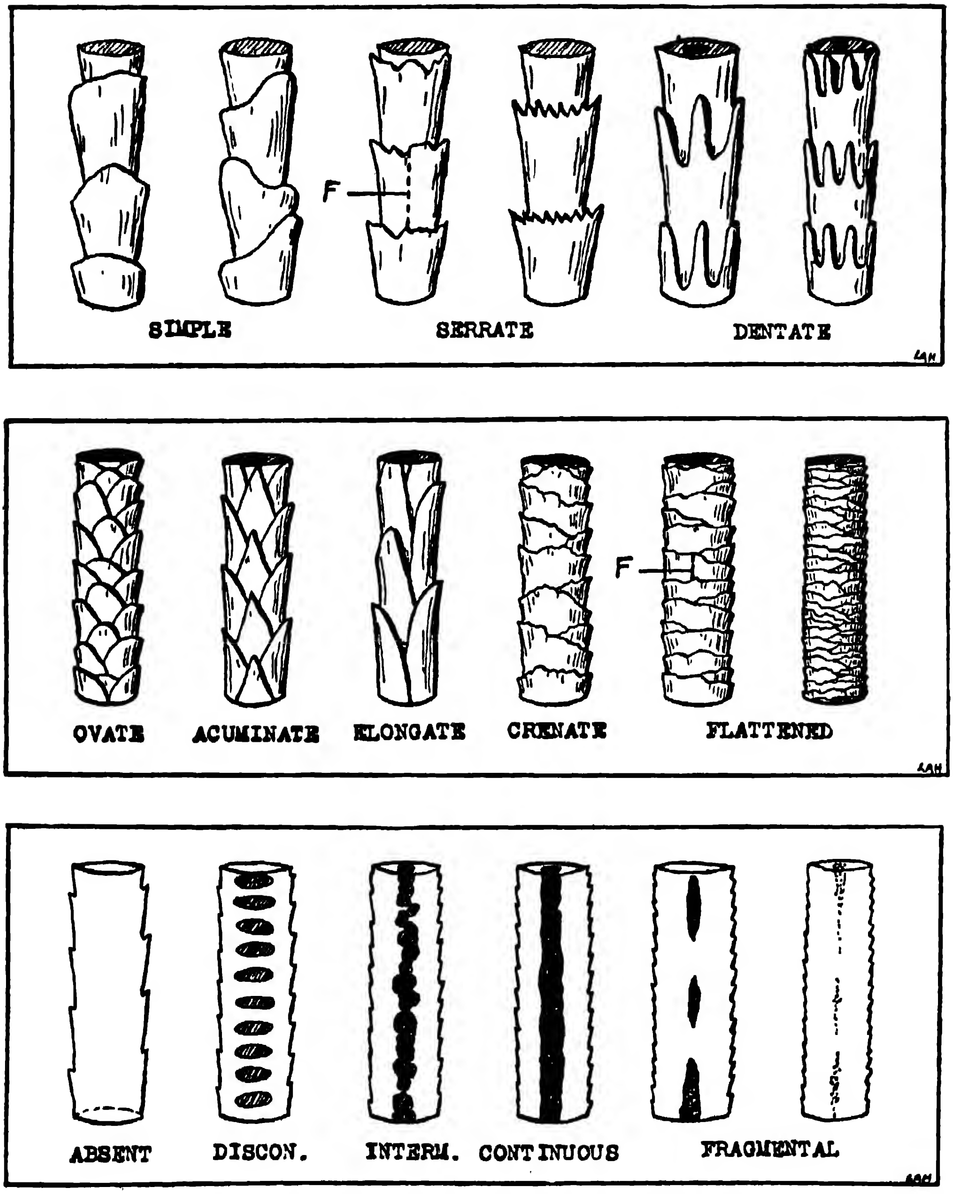


FIG. 2. TYPE FORMS OF CUTICULAR SCALES AND MEDULLAS OF MAMMALIAN HAIR. *Above:* CORONAL SCALES; *Center:* IMBRICATE SCALES; *Below:* MEDULLA TYPES.

the pigment granules, to which the color of the hair is primarily due (though in some cases this pigmentary substance is diffuse), located in and among the cells of the cortex, and to a less extent in the medullary column, and (4) the cuticle or outermost investiture of the hair shaft, composed of thin, horny, transparent plates of keratized protoplasm, of a multitude of pleasing forms and relationships.

After the hair shaft has made its appearance above the level of the epidermis and its various parts are cornified (keratized) and hardened, it may be termed a mature hair shaft. Thereafter there is but little change in the relationships of its various parts, though the forms of its various structural elements undergo some modifications (differing with different species of mammals) as the shaft increases in length. As far as any physiological connection with the epidermal layer which gave it birth is concerned, the hair shaft is a dead structure. No blood or nerve supply is carried up into its shaft, these ending in the papilla, and the hair shaft is increased in length by additions to its base from the proliferations of the cells of the papilla. It seems impossible, therefore, that hair should turn white overnight (as is often stated), as the pigments once pushed out inside the hair shaft have no vital connection with the blood supply. Whitening of hair overnight (or within a very few days) has often been claimed, but not proved. Apparently the only way in which hair can turn white is through a failure of the cells of the papilla to produce their natural pigmentary secretions while the hair shaft is being formed. As the new material of the shaft is gradually pushed out, it emerges as a colorless (*i.e.*, in the case of humans, white) hair. But this process would produce a completely white hair, that is, white from base to tip, only after a growth of some months. This is elsewhere discussed in connection with the life of a single hair shaft.

In this paper, the discussion of the forms and relationships of the four structural elements of the hair shaft (unless otherwise noted) concerns itself with the condition of these elements as found midway between the distal and proximal ends of representative mature hair shafts.[1]

In discussing mammalian hair it is convenient to assign the mammals to two groups, the *Infrahominidae* (mammals below man) and the *Hominidae* (man himself). With respect to the scalation of mammal hairs in general, the scales fall naturally into two form-groups: the coronal scales and the imbricate scales. The coronal scales (Fig. 2, above) completely encircle the cortical cylinder of the hair shaft and may be likened to glass tumblers, without bottoms, set one within another, their free ectal edges sculptured in various forms. The imbricate scales (Fig. 2, center) do not individually encircle the cortical cylinder, but are arranged like the scales of a fish or the shingles on a roof, and their free distal edges are likewise etched into different shapes.

Cuticular Scales of the *Infrahominidae*

One of the most interesting and surprising relationships which came to be appreciated as the cuticular scales of the infrahominid mammals were studied was that, in general, the size of the scales

[1] All figures, unless otherwise described, show these structures as they occur in this region of the shaft. The figures of hair shafts are not drawn to scale, since the diameters of some of the shafts shown are as great as 150 microns, and others as little as 6 microns. The practice here has been to draw all shafts *above* 30 microns as if they were of one diameter, and all shafts *below* this as if they were of one smaller diameter. All drawings are original delineations, or micrographs, made directly from the microscope, the size relationships being determined with the ocular micrometer.

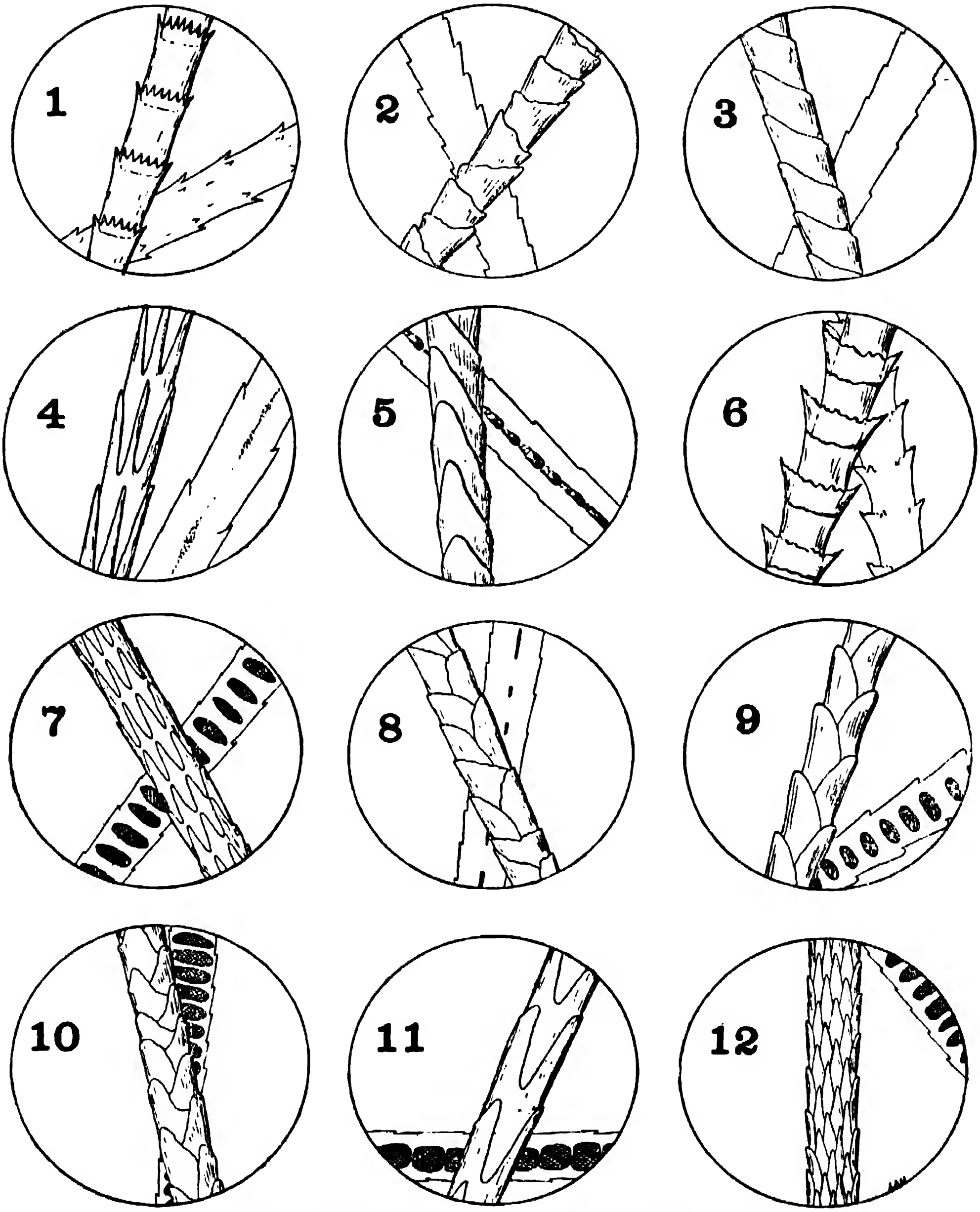


FIG. 3. SOME FORMS OF CORONAL AND IMBRICATE SCALES AND MEDULLAS OF MAMMALIAN HAIR SHAFTS. ALL SHAFTS DRAWN AS THOUGH OF THE SAME DIAMETER, THOUGH THEY RANGE FROM 6.80 MICRONS (NO. 1, INTERMEDIATE BAT) TO 27.20 MICRONS (NO. 8, THREE-TOED SLOTH). 1. INTERMEDIATE BAT (*Mormops intermedia*). 2. PHYLLOPS (*Phyllops falcatus*). 3. RED BAT (*Lasiurus borealis*). 4. EUROPEAN OTTER (*Lutra vulgaris*). 5. EUROPEAN BEAVER (*Castor fiber*). 6. WRINKLED LIPPED BAT (*Nyctinomus bocagei*). 7. CALIFORNIA SEWELLEL (*Aplodontia californica*). 8. THREE-TOED SLOTH (*Bradypus tridactylus*). 9. GIANT GOLDEN MOLE (*Chrysochloris trevelyani*). 10. STRAND MOLE RAT (*Bathyergus maritimus*). 11. MINK (*Mustela vison*). 12. BAIRD'S SHREW (*Sorex bairdi*).

(*i.e.*, their antero-posterior width) and their forms varied together in a constant way. Moreover, the size (and hence also the forms) of the scales bore a relationship, not to the species of mammal bearing the hair, but to the diameter of the hair shaft bearing the scales. Thus it may be said that, knowing the diameter of the hair shaft, one can predict what sort of scales will be found upon it. In the finest and softest hairs (*i.e.*, those of least shaft diameter), one encounters only the coronal type of scales. These scales occur in a great variety of forms, which fall into the following elemental types (Fig. 2, above): (1) simple, (2) serrate, (3) dentate. Modifications of these types occur in very interesting relationships, some with respect to the diameter of the hair (minute modifications of the contours of the free ectal edges of the scales which do not disturb the classification just mentioned); some with respect to their positions on the hair shaft (whether proximal, distal or medial); some apparently with respect to the vigor or languor of the papillal cells; some with respect to the species, in a way not yet understood, and now the subject of study in the writer's laboratory. In Fig. 3, 1 to 7, are shown some typical coronal scale forms. It is interesting to note that the bats, whose habits are more like the birds than are those of any other vertebrate and which have need of a light body covering which shall give at once the maximum of heat-insulating qualities with the minimum of weight, have developed, as a group, a hair which in its superficial configuration and in its actual effect *en masse* upon the body is, of all vertebrate integumental structures, most like a feather.

Upon the shafts of hairs coarser than those of the bats (those roughly above 8.50 microns in diameter) one finds almost exclusively the imbricate type of scales. These may be grouped into five appreciably distinct groups (Fig. 2, center): (1) ovate, (2) acuminate, (3) elongate, (4) crenate and (5) flattened. Some representative modifications of these five types may be seen in Fig. 3, 8 to 12, and Fig. 4, entire figure.

In Fig. 5 is shown graphically the relationship existing between the scale types and the shaft diameters of infrahominid mammals. The fractional numbers in decimal along the curve are the scale indices, which are the expressions of the ratio of the size of the scale to the diameter of the hair shaft. By size of scale is meant the length of the free proximo-distal diameter of the scale, as shown by the letter F in Fig. 2, above and center.[2] The smaller the hair, then, the larger the scales, and their forms follow. In discussing this graph, it must be remembered that the associations represented deal with large groups and averages. The coincidence of scale form and scale size is as though the hair shafts, increasing in diameter, pull out and flatten the cuticular scales proximodistally and, except in the case of some of the hairs of greatest diameter, smooth out their distal edges. These differences in form are the results of the differences in the activities of the cells of the hair papilla, plus also, it is believed, some differences in the gradual drying out of the hair shaft, plus also the effects of wear on the free ectal edges of the scales, particularly at the tips of the shaft. The activities of the papillal cells produce differences both at the tip and the base of the hair shaft, *i.e.*, when these cells begin, and close, their mitosis. Along the middle of the shaft the scales are fairly uniform in shape and relationships. Differences in the organization of the medullary column and pigmentation

[2] Where the diameter of the hair shaft = D and the proximodistal diameter of the free surface of the cuticular scale = F and the scale index = I, the equation is $\frac{F}{D} = I$.

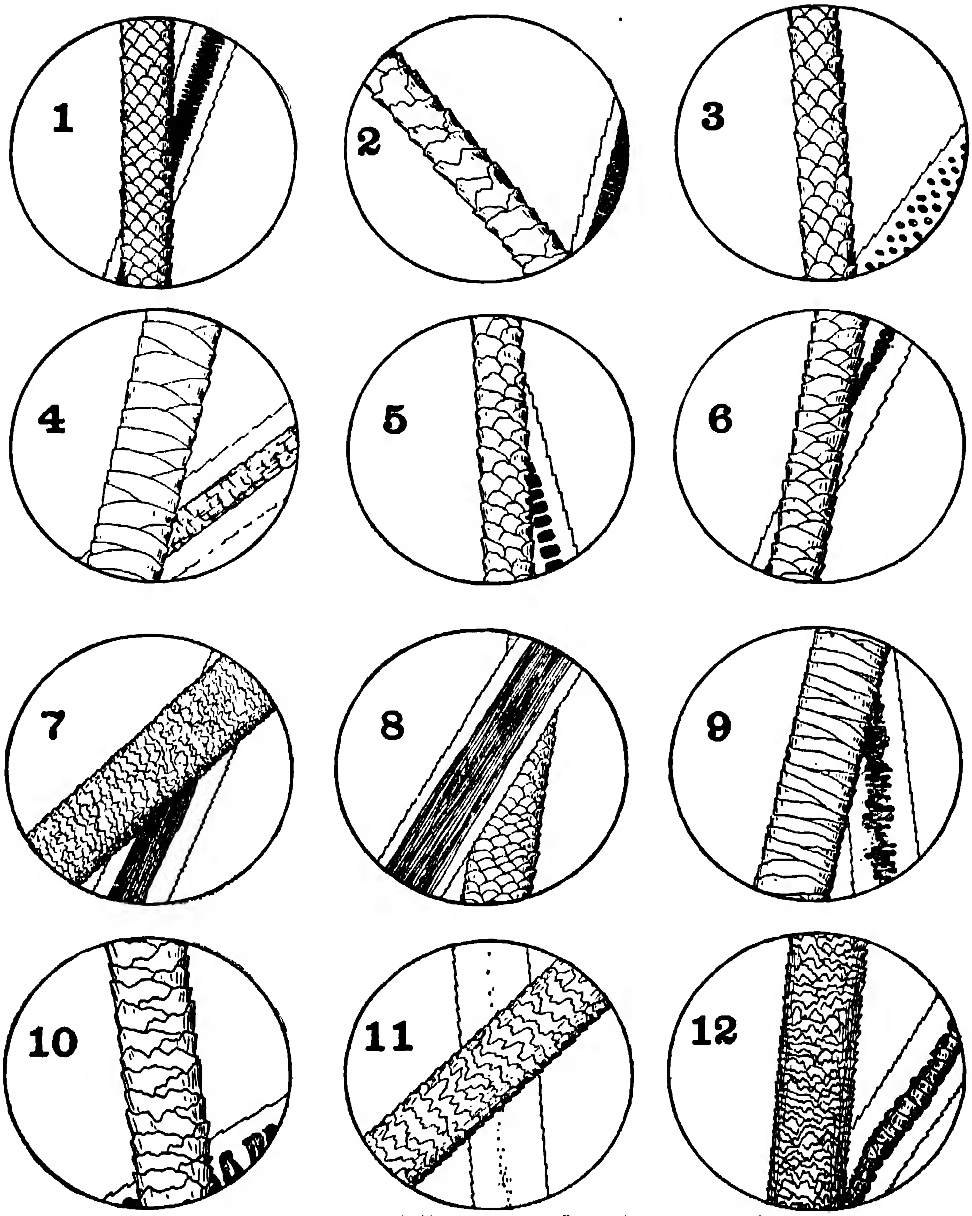


FIG. 4. SOME FORMS OF IMBRICATE SCALES AND MEDULLAS OF MAMMALIAN HAIR SHAFTS. SHAFTS ARE DRAWN AS THOUGH THEY WERE OF TWO DIAMETERS: THOSE ABOVE 30 MICRONS OF ONE SIZE, AND THOSE BELOW 30 MICRONS OF ANOTHER. THE SHAFTS HERE SHOWN RANGE IN DIAMETER FROM 20.00 MICRONS (NO. 5, TANA) TO 158.00 MICRONS (NO. 9, SEA LION). 1. THIBETAN SUN BEAR (*Helarctos thibetianus*). 2. PATAS MONKEY (*Cercopitheous patas*). 3. POCKET RAT (*Thomomys nevadensis*). 4. GREAT ANTEATER (*Myrmecophaga tridactyla*). 5. TANA (*Tana chrysura*). 6. SAGOUIN (*Hapale penicillata*). 7. PERCHERON MARE. 8. TRUE'S WHITE TAILED DEER (*Odocoileus truei*). 9. NORTHERN SEA LION (*Eumentopias stelleri*). 10. TITI (*Callithrix jacchus*). 11. PEBA ARMADILLO (*Tatu novemcincta*). 12. HEDGEHOG (*Erinaceus hindei*).

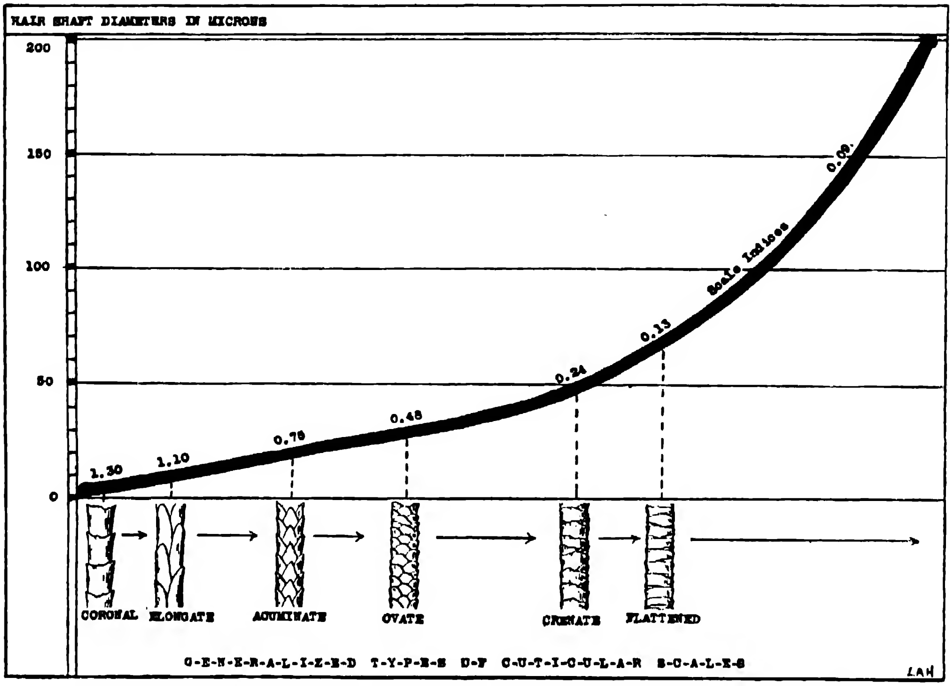


FIG. 5. RELATIONSHIP BETWEEN THE CUTICULAR SCALE FORM AND THE HAIR-SHAFT DIAMETERS OF INFRAHOMINID HAIRS, AS SHOWN BY THE STUDY OF 217 SAMPLES OF SUCH HAIRS, FROM SPECIES REPRESENTING ALL THE EXISTING ORDERS OF MAMMALS EXCEPT THE *Cetacea* (WHALES AND THEIR KIN). THE GENERAL REGIONS OF THE OCCURRENCE OF THE SCALE FORMS ARE SHOWN ALONG THE ABSCISSA, THE AVERAGE SCALE INDICES ALONG THE CURVE.

are also to be seen along the length of the hair shafts. The lifetime of a papilla (synonymous with the lifetime of a hair), that is to say, the time during which the proliferation of its cells (and the consequent formation of the hair shaft) is continuous, is said to be, for the human head hair, between five and six months. When a hair shaft is about to be shed, the proliferation of its papillal cells ceases; the papilla itself gradually atrophies, and then becomes cornified. The hair shaft, pulled away at its base from the papilla, is pushed outward toward the mouth of the follicle by the continued multiplication of the cells of the root sheath, and finally drops out of the follicle. Or it may be pushed out by the growth of a new shaft, from the renewed activity of new cells upon a rejuvenated papilla. In some species of

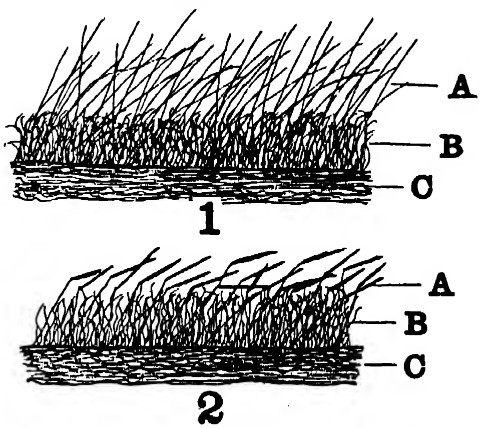


FIG. 6. RELATIONSHIP OF PROTECTIVE HAIR TO FUR

1. IN A TYPICAL MAMMAL. 2. IN THE DUCK-BILL (*Ornithorhynchus anatinus*). *A.* PROTECTIVE (OVER) HAIR. *B.* FUR (UNDER) HAIR. *C.* SKIN.

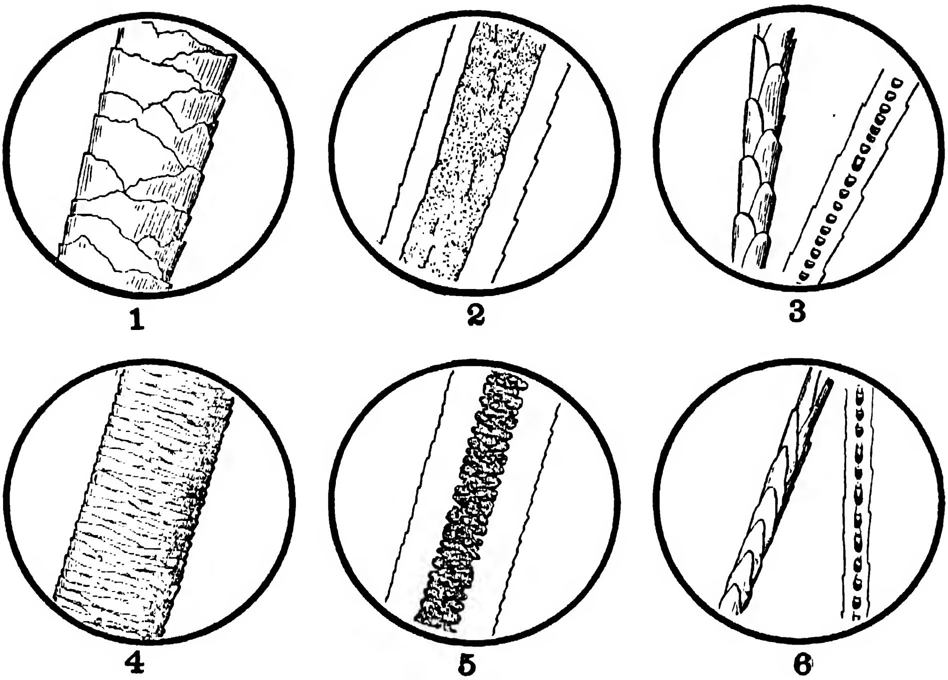


FIG. 7. STRUCTURAL DIFFERENCES

BETWEEN THE PROTECTIVE HAIRS AND THE FUR HAIRS, AS ILLUSTRATED IN TWO COMMON SPECIES OF MAMMALS. *Above,* THE COMMON SKUNK (*Mephitis mephitis*). 1. SCALATION OF THE PROTECTIVE HAIR. 2. MEDULLATION OF THE PROTECTIVE HAIR. 3. SCALATION (LEFT) AND MEDULLATION (RIGHT) OF THE FUR HAIR. *Below,* THE EUROPEAN BEAVER (*Castor fiber*). 4. SCALATION OF THE PROTECTIVE HAIR. 5. MEDULLATION OF THE PROTECTIVE HAIR. 6. SCALATION (LEFT) AND MEDULLATION (RIGHT) OF THE FUR HAIR. IN THIS INSTANCE THE HAIR SHAFTS IN EACH ROW ARE DRAWN TO SCALE.

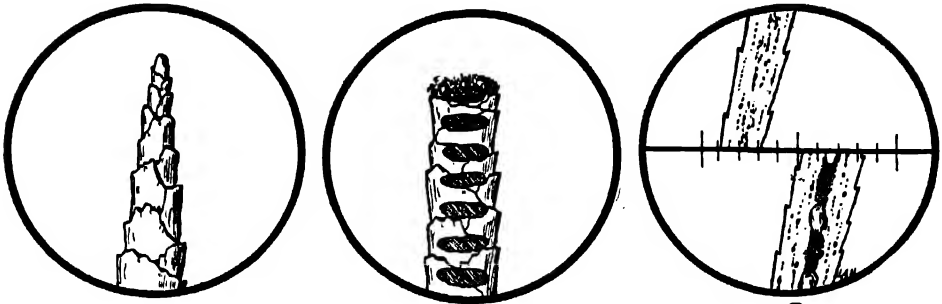
mammals this renewed and seasonal atrophy of the papilla gives rise to the familiar phenomenon of moulting.

Cuticular scales may vary in a slight way with the shape of the cross-section of the hair shafts. Shafts are, in general, circular or elliptical in cross-section and do not vary from this much between base and tip, but there are instances of hair shafts with broad, flattened, spear-head-like tips, as, for example, in the over-hairs of the duckbill (*Ornithorhynchus anatinus*),[8] Fig. 6, 2A, and other aquatic forms. In this case, the cuticular scales on the broadened tip portion of the shaft are different in form from those on the smaller middle and basal portions of the shaft.

Pathological conditions within the follicle give rise to abnormal hair forms, as in monolethrix, trichorrhexis and others. Asymmetry in the development of medulla, cuticle and pigment depositions has been found by the writer to be fairly common in human head hair.

In many species of mammals two sorts of hair are produced; a long, coarse, over-hair, or protective hair, and a shorter, softer, under-hair, or fur hair (Fig. 6). The forms of the scales of these two sorts of hair follow the law of

[8] L. A. Hausman, "A Micrological Investigation of the Hair Structure of the Monotremata," *Am. Jour. Anat.*, 27: 463, 1920.



1 2 3

FIG. 8. HOW CLIPPING WEAKENS FUR

1. TIP OF THE SHAFT OF AN UNCLIPPED HAIR OF RABBIT OR HARE. 2. CUT END OF A CLIPPED RABBIT HAIR SHAFT. NOTE HOW THE CLIPPING AT ONCE ROBS THE END OF ITS PROTECTIVE COVERING OF CUTICULAR SCALES AND EXPOSES THE END TO FRAYING OUT. 3. THE USE OF THE COMPARISON OCULAR IN IDENTIFYING FUR HAIRS. THE HAIR SHAFT OF A GENUINE AMERICAN OTTER ABOVE, AND THE NUTRIA OR COYPU RAT BELOW, SOMETIMES USED AS A SUBSTITUTE. NOTE HOW THE GRANULATION AND MEDULLATION TELL THE STORY AND AFFORD A CERTAIN CRITERION FOR IDENTIFICATION. NOTE ALSO THE DIFFERENCES IN SHAFT DIAMETERS.

shaft-diameter association just explained (Fig. 7).

In spite of the fact that, in general, the forms of the cuticular scales bear relationship to shaft diameter rather than to species, there are sometimes present minute apparently specific differences in the sculpturings of the free ectal edges of the scales. These are not yet fully understood or classified, nor is it yet certain that they are specific differences, and one part of the work in the writer's laboratory is being focused upon this aspect of the problem of hair structure relationships. Enough, however, is known about the diagnostic value of some of these possibly specific scale-configuration criteria to show that it is possible to identify the species-source of a hair sample from the cuticular scales alone. Where this criterion fails, we still may have recourse to the diagnostic characters offered by the structure of the medulla and the pigment bodies, of which we shall speak later.

The cuticular scales form a protective covering around the cortex of the hair shaft which prevents its splintering out and wearing away. It is for this reason that, with respect to furs used as garments, clipping greatly weakens the individual hairs against wear, and results

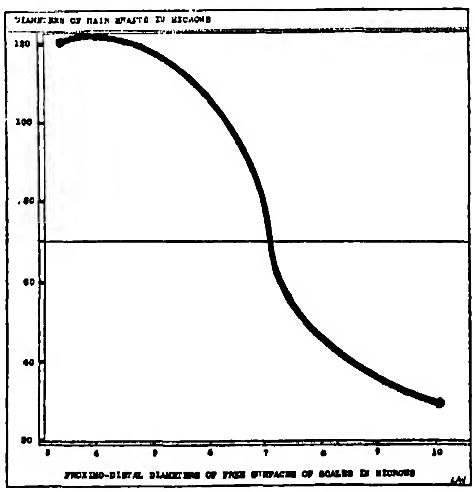


FIG. 9. RELATIONSHIPS BETWEEN THE SIZES

(*i.e.*, PROXIMO-DISTAL DIAMETERS OF FREE SURFACES) OF THE CUTICULAR SCALES, AND THE DIAMETERS OF THE HAIR SHAFTS AS SHOWN BY A STUDY OF 122 SAMPLES OF HUMAN HEAD HAIRS, REPRESENTING ALL THE EXISTING RACES OF MANKIND.

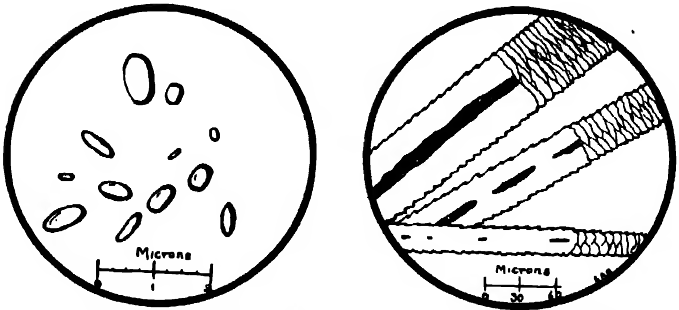


FIG. 10. HAIR SHAFTS AND THEIR PIGMENT GRANULES

Left: PIGMENT GRANULES FROM THE CORTEX OF HUMAN HEAD HAIR SHAFT, TO SHOW THE NORMAL VARIATION IN SIZE AND SHAPE. *Right:* THREE HAIR SHAFTS FROM THE RIGHT TEMPORAL REGION OF THE SAME HEAD, SHOWING THE VARIATION WHICH MAY OCCUR. THE BASAL PORTIONS OF THE SHAFTS HAVE BEEN CLEARED TO SHOW THE MEDULLAS.

in the production of a less durable fur than would have been the case had the hairs been left with their natural tips. In Fig. 8 is shown the appearance of clipped and unclipped rabbit hairs. Whenever a hair shaft is clipped, it presents, under the microscope, the appearance shown in Fig 8, 2. The friable cortex and medulla elements are left to fray out without the natural protection of the hard, smooth investiture of the cuticular scales, as shown in the natural hair tip (Fig. 8, 1). In hair shafts with smaller medullary columns than those of the rabbit or hare, the rate of wear of the clipped fur is relatively less, but is still more rapid than that of the same fur with its natural tips left intact.[4] This difference in the rate of wear of furs with clipped and unclipped ends has been accurately measured by an apparatus termed the tribometer (wear measurer) devised and used by the writer some years ago.[5]

Cuticular Scales of the *Hominidae*

The cuticular scales of human head hair are of the flattened type (Fig. 2, center), and vary in size with the diameter of the hair shaft as do the scales of the *Infrahominidae*. A graphic expression of this variability is shown in Fig. 9. As the hair shaft becomes smaller, the scales become larger, and tend toward the ovate forms. This is important, for it means that scale forms are, therefore, unrelated to race.[6] It has been found that the diameters of hair shafts from the same head may vary quite considerably, not only at different ages, but contemporaneously. This is accompanied by the characteristic variation in the scales (Fig. 10, right). And Wynkoop[7] has shown recently that the scales (as well as the medullas) bear relationship not to the age of the individual, but to the diameter of the hair shaft in which they occur. No differences in this flattened type of scale analogous to the supposititious specific differences noticed in the hairs of the *Infrahominidae* have been found. This is interpreted as being the cuticular scales indication that mankind is a single species.

[4] Moreover, a hair robbed of its flexible tip becomes stiffer and hence more likely to break under the strain of to and fro rubbing.

[5] L. A. Hausman, "Measuring the Durability of Furs," *Sci. Am. Monthly*, September, 1921 (published formerly by the *Scientific American* publishing company, but now discontinued).

[6] L. A. Hausman, "A Comparative Racial Study of the Structural Elements of Human Head Hair," *Am. Nat.*, 59: 529, November–December, 1925.

[7] E. M. Wynkoop, "A Study of the Age Correlations of the Cuticular Scales, Medullas and Shaft Diameters of Human Head Hair," *Am. Jour. Phys. Anthrop.*, 13: 177, No. 2, July–September, 1929.

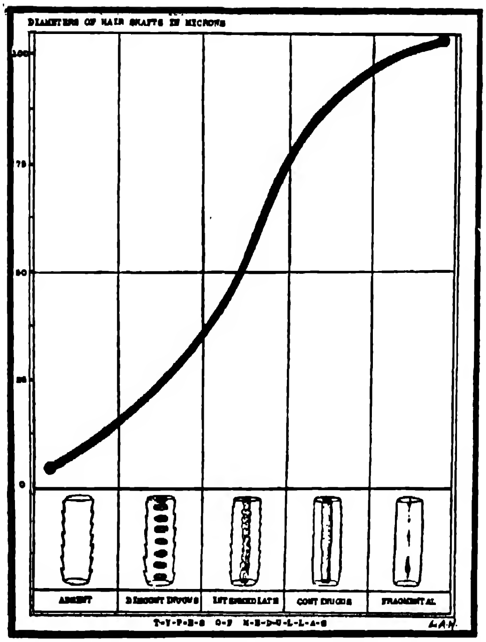


FIG. 11. GRAPHIC REPRESENTATION OF THE PRINCIPLE

THAT THE MEDULLA FORM OF THE HAIR SHAFT VARIES WITH THE DIAMETER OF THE SHAFT, AS SHOWN BY 197 SPECIES OF MAMMALS BELOW THE *Hominidae*. ALL THE EXISTING ORDERS OF *Mammalia* ARE REPRESENTED BY THE HAIR SAMPLES USED IN THIS STUDY, EXCEPT THE *Cetacea* (WHALES AND THEIR KIN).

MEDULLAS OF THE *Infrahominidae*

The medullas of the hairs of the infrahominid mammals fall into five classes (Fig. 2, below): (1) absent, (2) discontinuous, (3) intermediate, (4) continuous and (5) fragmental. The discontinuous medulla is a series of isolated chambers or cells, of regular form and placentation, made up of variously shrunken and cornified elements and sometimes containing pigmentary materials. The intermediate and continuous medullas seem to represent progressive coalescence stages of the first type, and the fragmental medulla the break-up and gradual disappearance of the fully fused, continuous type.

Many secondary specific variations in medulla form occur in infrahominid hairs, but with respect to the categories just listed, and with regularity, the relationships of the medulla *types* are not with species, but with the diameters of the hair shafts in which the medullas occur. The curve in Fig. 11 is intended to make this relationship clear. Thus among the bats one finds few medullas, most of the species being without this element. Among the smaller insectivores and rodents (bearing soft, fine hair) medullas of the discontinuous and intermediate types are prevalent, especially the former, while in the mammals bearing coarser hair (as the ungulates, primates, etc.) the continuous and fragmental medullas largely occur. Fre-

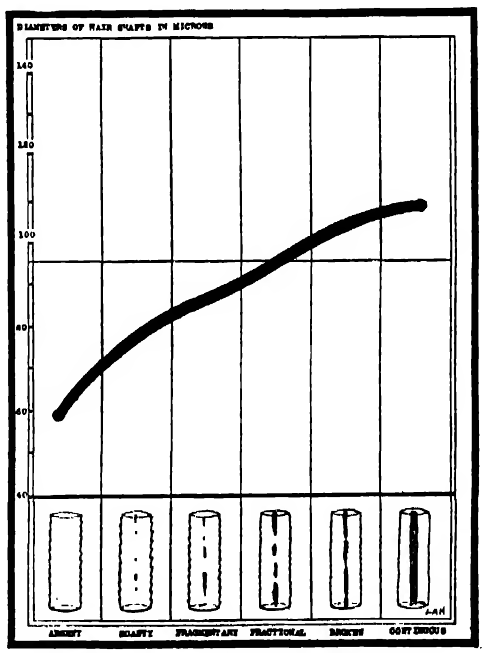
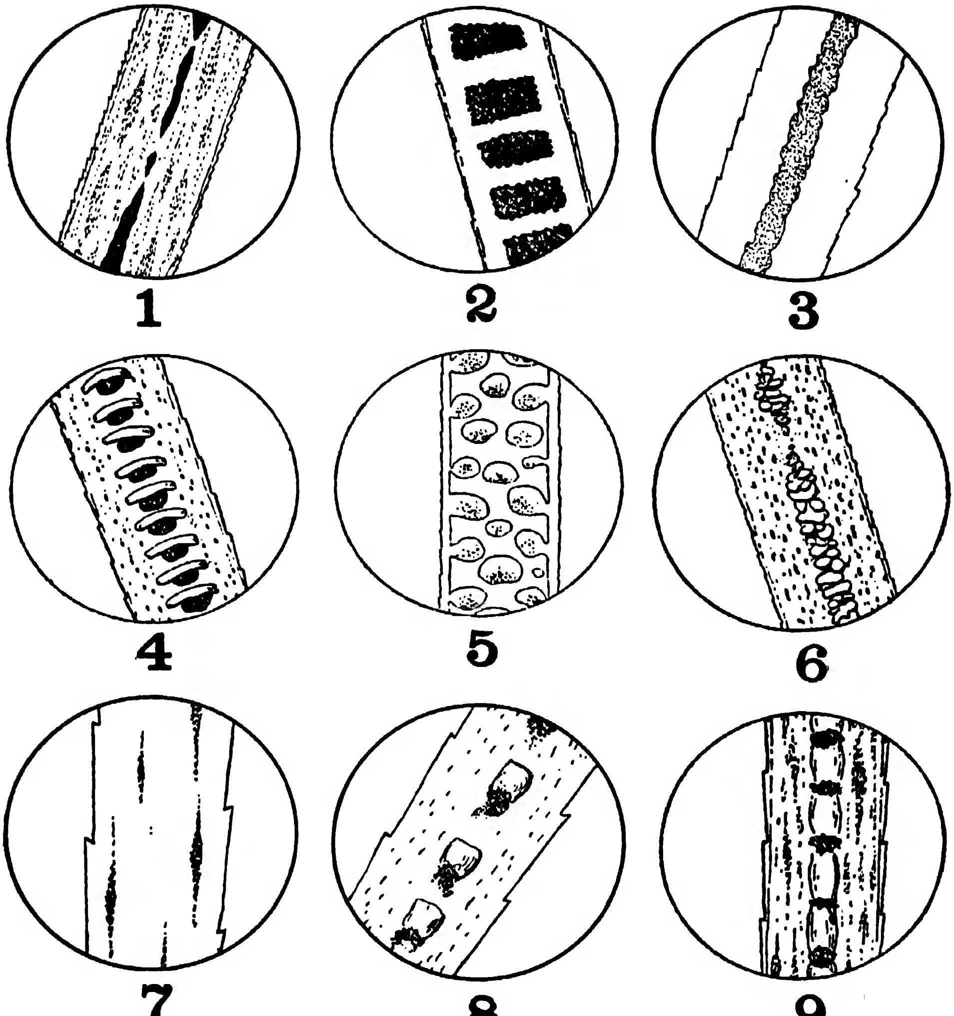


FIG. 12. HUMAN HEAD HAIRS

RELATIONSHIPS BETWEEN THE MEDULLA FORM AND THE HAIR-SHAFT DIAMETERS OF HUMAN HEAD HAIRS, AS SHOWN BY A STUDY OF 122 SPECIMENS OF SUCH HAIRS FROM INDIVIDUALS REPRESENTING ALL THE EXISTING RACES OF MANKIND.



1 2 3 4 5 6 7 8 9

FIG. 13. TYPES OF PIGMENT GRANULATION

IN THE HAIRS OF VARIOUS INFRAHOMINID MAMMALS, COMPARED WITH THAT OF MAN. 1. HEAD HAIR OF PRE-COLUMBIAN PERUVIAN MUMMY, TYPICAL OF THE GRANULATION IN A FUSCOUS BROWN HAIR. THE MEDULLA APPEARS BLACK BY TRANSMITTED LIGHT, BUT CONTAINS NO PIGMENT. 2. DARK GRAY HAIR OF THE SEWELLEL (*Aplodontia californica*), WITH THE PIGMENT MASSES IN THE MEDULLA. 3. PURE WHITE HAIR OF THE POLAR BEAR (*Thalarctos maritimus*), CONTAINING NO PIGMENT. 4. GRAYISH BROWN HAIR OF THE BLARINA (*Blarina brevicauda*), WITH PIGMENT MASSES IN THE MEDULLA AND GRANULES IN THE CORTEX. 5. GRAY HAIR OF THE SENNET KANGAROO RAT (*Perodipus sennetti*), WITH PIGMENT GRANULES IN MEDULLARY POCKETS. 6. DEEP-YELLOW HAIR FROM THE WRISTS OF THE SQUIRREL MONKEY (*Chrysothrix sciurea*), WITH THE PIGMENT IN THE FORM OF ELONGATED GRANULES IN THE CORTEX. 7. BROWN HAIR OF THE BROWN BAT (*Vespertilio fuscus*), THE PIGMENT IN THE FORM OF GRANULES ARRANGED IN PATTERNS SIMILAR TO THOSE IN HUMAN HAIRS. 8. BROWN HAIR OF THE NEW YORK WEASEL (*Putorius noveboracensis*), WITH ITS PIGMENT IN MEDULLARY GRANULAR MASSES AND CORTICAL GRANULES. 9. DARK BROWN, ALMOST BLACK HAIR OF THE BLACK BEAR (*Ursus americanus*), THE PIGMENT IN THE FORM OF GRANULAR MEDULLARY MASSES AND CORTICAL GRANULES ARRANGED IN OVAL PATTERNS AS IN HUMANS.

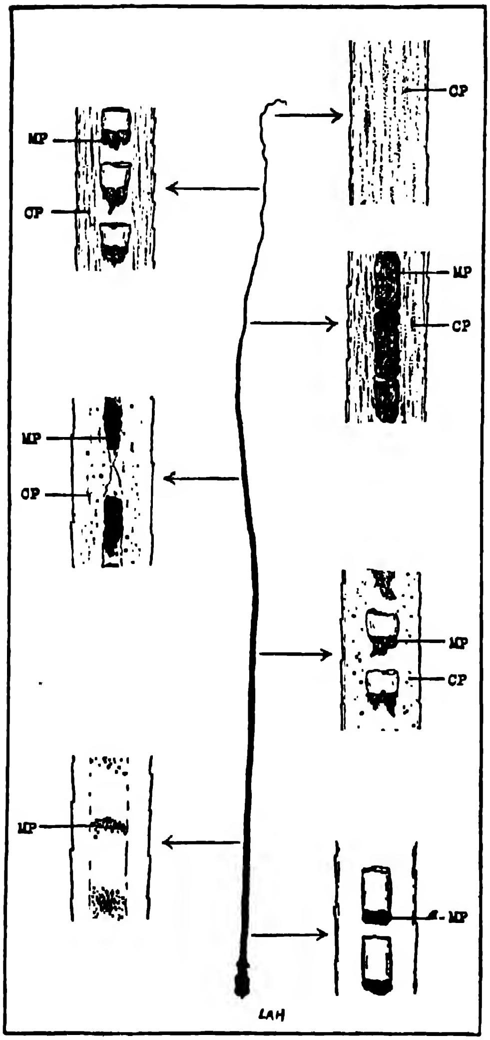


FIG. 14. CHANGES IN THE PIGMENTATION CHARACTERS

FROM THE BASE TO THE TIP OF A SINGLE FUR, OR UNDER HAIR FROM THE MUSKRAT (*Fiber sibetheous*), OCCURRING IN THE REGION OF THE MEDULLARY COLUMN. NOTE THAT, IN THIS HAIR SHAFT, THE PIGMENT MASSES AT THE BASE OF THE SHAFT WERE CONFINED TO THE MEDULLA; THOSE AT THE TIP WERE IN THE FORM OF GRANULES IN THE CORTEX, WHEREAS AT ALL OTHER POINTS (EXCEPT NO. 2) THE HAIR SHAFT OWED ITS COLOR TO A COMBINATION OF THESE TWO TYPES OF PIGMENTATION. *MP*—MEDULLARY PIGMENT; *CP*—CORTICAL PIGMENT.

quently one encounters very large, coarse hairs in which the medulla is lacking altogether, having apparently arrived at this state through the disappearance of a medulla of the fragmental type.

MEDULLAS OF THE *Hominidae*

Medullas of human head hair have been regarded as a separate subtype of the continuous type established for mammal hair in general, and are grouped as follows (Fig. 12): (1) absent, (2) scanty, (3) fragmentary, (4) fractional, (5) broken and (6) continuous. Here again the relationships of these medulla types is not with age[7] or with race,[8] but with the diameters of the hair shafts, as indicated by the graph in Fig. 12. The coarser the hair the more nearly continuous and solid is the medullary column, though many variations may occur. And since hair shafts from the same head may vary in diameter, the medullas which they show may vary correspondingly. It is only when one has examined a large series of hair samples from individuals representing many races and ages that the true status of the distribution and relationships of the microscopic elements of hair shaft structures becomes appreciable.

It is interesting from the standpoint of what has been said regarding the close parallelism between both scale and medulla form and the diameter of the hair shaft to note what a comparison of the two curves (Figs. 11 and 12) reveals: (1) that in both hominids and infrahominids the hair shafts of about the same diameter (in the neighborhood of 80 to 100 microns) bear very nearly the same types of medullas, and (2) that the hominid hairs do not show the discontinuous or intermediate types exhibited by the hairs of the infrahominid species. No matter how small the diameters of hominid hairs, the discontinuous and intermediate types of medullas

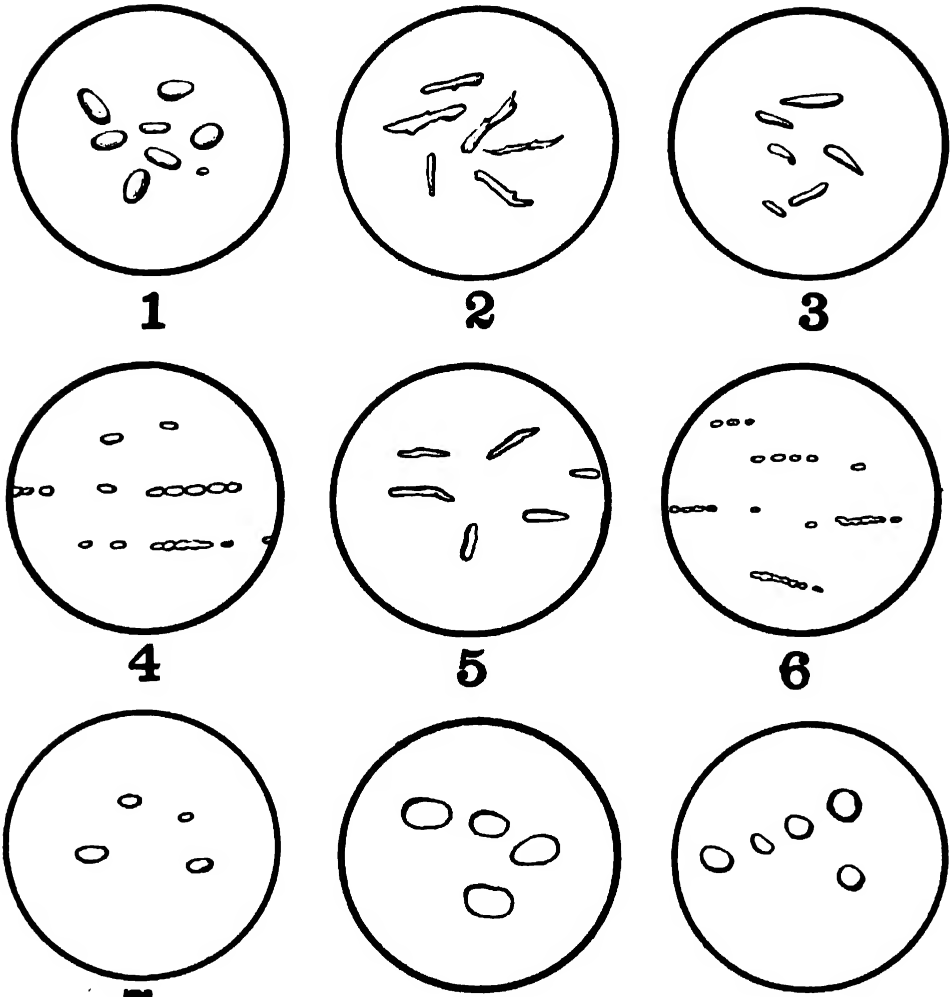


FIG. 15. VARIOUS FORMS OF PIGMENT GRANULES

OCCURRING IN THE CORTICES OF MAMMALIAN HAIR SHAFTS: 1. HEAD HAIR OF MAN (APACHE INDIAN), BLACK. 2. WRIST HAIR OF THE SQUIRREL MONKEY (*Chrysothrix sciurea*), YELLOW. 3. FUR HAIR OF THE AMERICAN OTTER (*Lutra canadensis*), BROWN. 4. FUR HAIR OF THE SEA OTTER (*Latax lutris*), BROWN. 5. FUR HAIR OF THE BLACK BEAR (*Ursus americanus*), BLACK. 6. HAIR OF THE BROWN BAT (*Vespertilio fuscus*), LIGHT BROWN. 7. FUR HAIR OF THE COYPU (*Myocastor coypus*), BROWN. 8. TIP OF THE FUR HAIR OF THE MUSKRAT (*Fiber zibethicus*), LIGHT BROWN. 9. PROTECTIVE HAIR OF THE FUR SEAL (*Callorhinus alascensis*), BROWN.

never make their appearance. This looks again as though we were dealing with a single species of mammal, though, as has been pointed out, such major variations in medulla form do not occur in any specific relationship among the *Infrahominidae*. The closest structural approach made to human hair shafts is to be found in the hairs of the lower *Primates*, where, as notably in the cases of the Hoolock gibbon, gorilla and Schweinfurth's chimpanzee, the approach is close indeed.

Pigmentation of Infrahominid Hair

In mammalian hair in general the color is produced by pigmentary substances within the cortex or medulla of the hair shaft and, though but seldom, by pigment secretions from skin glands upon the outer surface of the cuticular scales. No matter how the color of a hair is produced, it may be modified by the way in which the light is reflected from and refracted by the keratized cells of the cortex and medulla and by the cuticular scales.

In the hairs of the infrahominid mammals the pigmentary materials may be in the form of discrete granules, large amorphous masses or diffuse stain. The granules are found in and among the elongate cells of the cortex and in the medullary column. The large amorphous masses occur almost entirely in the medullary column, though sometimes the granules of the cortex may become agglomerated into somewhat similar masses. The diffuse stain colors the cortical cells or the elements of the medulla, but does not stain the cuticle (this offers a useful criterion for judging whether the hair shaft has been artificially colored, in which case the cuticular scales are stained). Pigment, elaborated by skin glands and secreted upon the outer surfaces of the cuticular scales, is comparatively rare as a hair shaft color, being found, for example, on the hairs of the flanks and base of the tail of the ermine species (***Mustela***) where it tints those portions of the white winter pelage a pale yellow.

Fig. 13, 2 to 9, shows several characteristic modes of distribution of pigment granules and masses in the hairs of infrahominid mammals, compared with the cortical pigment granules of the hairs of humans (Fig. 13, 1). Pigmentation characters in the *Infrahominidae* are related to species and not primarily to hair color, though there seems to be evidence (now being accumulated) that some sort of problematical color association of a secondary kind does exist. In hair shafts certain structural and distributional variations in pigmentation exist along the length of the same shaft. The pigmentation at the basal portion of the shaft may be quite different from that midway in its length, and this, in turn, different from that found at its tip. In some species as many as seven appreciably different kinds of pigmentation characters may be seen (Fig. 14). A closer study of the pigmentation of hair shafts indicates that, in the first place (ignoring for the time the modifying effects of reflection and refraction), the color of the hair depends upon the size of the pigment bodies (whether they are disjunct granules or masses), and in the second place, to their numbers in cortex or medulla. An examination of the individual granules in the cortex shows that all shades of brown, from a light straw yellow-brown to almost a black, accompany a progressive increase in the size of the granules. Many factors unite to modify these brown colors, such as distance from the medulla, character of the medulla, presence of diffuse stain in the cortex and the like.

Pigmentation of Hominid Hair

The pigmentation of human hairs differs from that of the infrahominid hairs in two particulars: first, the pigment is

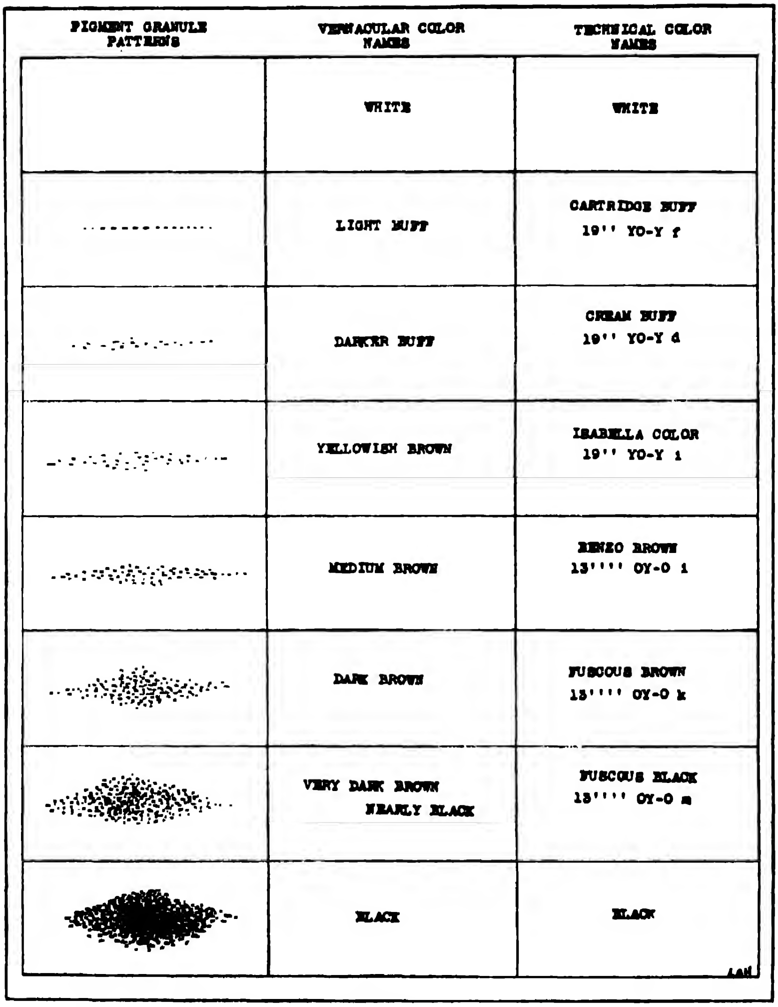


FIG. 16. THE RELATIONSHIP BETWEEN COLOR OF HUMAN HEAD HAIR AND THE PIGMENT GRANULE PATTERNS IN THE CORTEX OF THE HAIR SHAFT. THE TECHNICAL DESIGNATIONS OF THE COLOR VALUES AS INDICATED IN THE COLUMN ON THE RIGHT ARE TAKEN FROM RIDGWAY'S "COLOR STANDARDS AND COLOR NOMENCLATURE."

present as diffuse stain or as granules (or both), but the granules are not agglomerated into such amorphous masses; and second, it is restricted to the cortex of the shaft and but seldom appears in the medulla, and only in one or two instances known to the writer has it appeared in the keratin of the cuticular scales. Cortical granules and cortical diffuse stain (one or both together), then, account for the hues of human hair.

The pigment granules of the cortex of human head hair are spherical, ovoid or ellipsoid (Fig. 10, left, and Fig. 15, 1), whereas in other mammals variously shaped granules are encountered (Fig. 15, 2 to 9), though ovoid granules are also quite common. This is of use in identifying minute fragments of hair

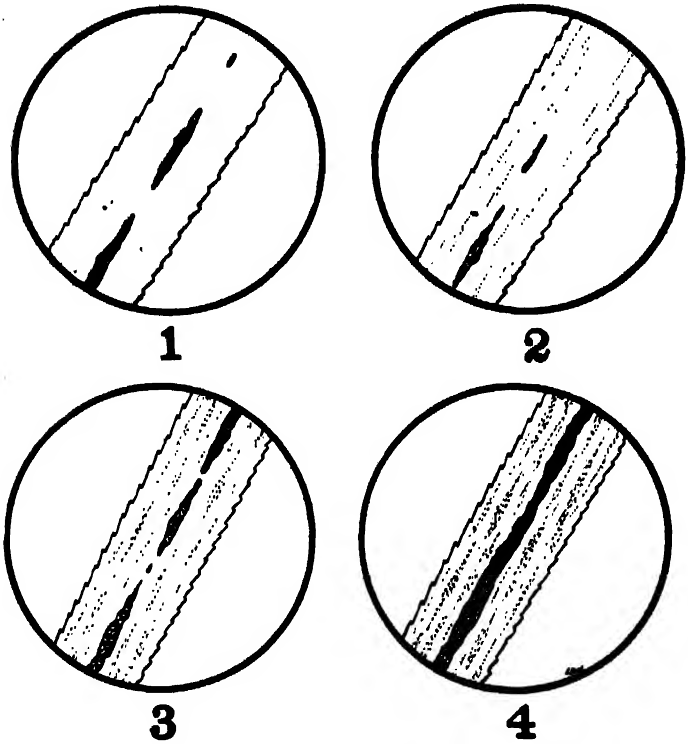


FIG. 17. CORTICAL PIGMENT GRANULES

IN HUMAN HEAD-HAIR SHAFTS, SHOWING THE RELATION OF THEIR NUMBERS AND ASSOCIATIONS TO THE COLOR OF THE HAIR. EACH MICROGRAPH REPRESENTS AN OPTICAL LONGITUDINAL SECTION ALONG THE SHAFT IN THE REGION OF THE MEDULLARY COLUMN. 1. HAIR OF AGED SWEDE, WHITE; FEW OR NO PIGMENT GRANULES. 2. HAIR OF LITHUANIAN, CREAM BUFF (RIDGWAY 19″ YO–Y d). 3. HAIR OF SOMALI, BENZO BROWN (RIDGWAY 13‴′ OY–O i). 4. HAIR OF PREDYNASTIC EGYPTIAN, FUSCOUS BROWN (RIDGWAY 13⁗′ OY–O k).

shafts, the scales of which may have disappeared and the medullas become distorted. At least, it may serve to assure the microscopist that he is dealing with a fragment of an infrahominid mammal rather than of a human being.

In hominid mammals, unlike the infrahominid, the pigment granules of the cortex of the hair are very definitely associated with the color of the hair, and the larger and more dense their aggregations, the deeper the hue of the shaft. The relations between these granule characteristics and the colors of the hair are shown in the table (Fig. 16). These color values may be altered by the presence of the diffuse stain which, under the microscope, by transmitted light is found to be of a lighter or darker yellowish hue. Where cortical pigment granules are few in numbers they are found aligned in slender rows of single sequence, and as they increase in numbers and give a darker hue to the hair shaft, they become grouped into lenticular associations, and these patterns become progressively and regularly more ovoid and their component granules more closely packed until the patterns seen in the black hairs are reached. The granule patterns vary widely, then, in shape, and this variation is associated with the

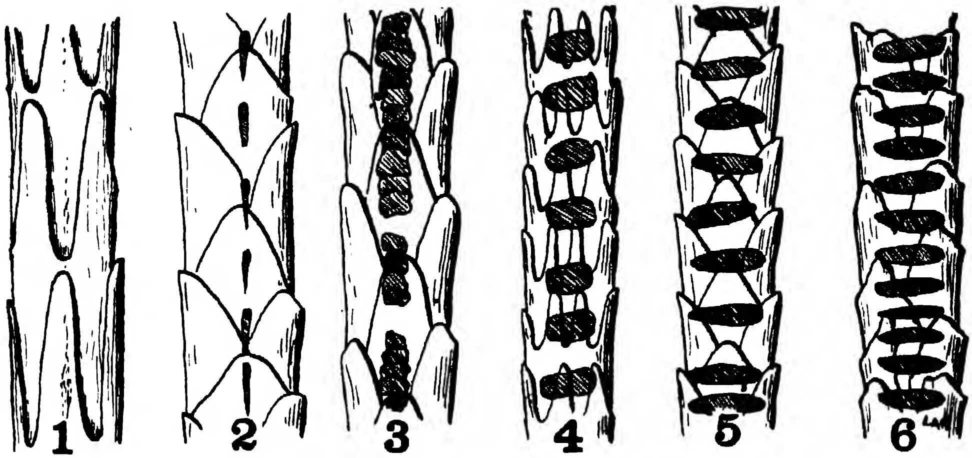


FIG. 18. SIX FUR HAIRS OF COMMERCE

SHOWING THE CHARACTER OF THE CUTICULAR SCALES AND MEDULLAS USED IN IDENTIFICATION. THESE ARE ARRANGED, ALSO, FROM ONE TO SIX, IN THE ORDER OF THEIR DURABILITY FROM THE STANDPOINT OF WEAR WHEN ON GARMENTS, REGARDING THE SEA OTTER FUR (ONE OF THE MOST DURABLE) AS 100. NOTE THAT THE DURABILITY OF A FUR STANDS IN INVERSE RELATIONSHIP TO THE EXPANSE OF THE MEDULLA. THUS, THE SEA OTTER HAIR SHAFT POSSESSES LITTLE OR NO MEDULLARY COLUMN, WHEREAS THE RABBIT AND HARE HAIR SHAFTS POSSESS A VERY LARGE ONE. ALL SHAFTS HAVE BEEN MAGNIFIED TO THE SAME SIZE. 1. SEA OTTER, DURABILITY 100. 2. RACCOON, 65. 3. LYNX, 25. 4. CHINCHILLA, 15. 5. EUROPEAN MOLE, 07. 6. RABBIT OR HARE, 05.

color of the hair and not with race. But here again are encountered slight variations which are problematical and which are, therefore, being further studied together with those variations of medullas and cuticular scales to which allusion has already been made.

In respect of the granules themselves, they range from a little less than 0.20 microns to a little more than 1.25 microns, along their major axes, and their color depth increases with their size. The largest granules were found in the hairs of members of the Bantu tribes (Negroid group), and in the light yellow hairs of the Norwegians.[9] This is indicative of the general status of the granules with respect to size, the smallest being found in the lightest hairs, the largest in the darkest. Fig. 17 shows the appearance of four hair shafts of colors from light to dark and their characteristic pigment granule patterns. Wherever diffuse cortical pigment is present in the hair shaft, the warm tones of reddish, coppery and Titian hues are produced. The more granules (with this combination) the more brownish and Titian, and the fewer granules the more clear orange-red and metallic is the color.

With respect to the application of the study of the microscopic structures of hair much might be said, did the limits of this paper allow it. It may be briefly pointed out, however, that wherever an examination of hair shafts is necessary to determine the species source of samples (in the case of infrahominid hairs) a knowledge of the structural elements of hairs is of the greatest value. In the fur and fabric industries, for example, microscopic examinations are often desirable. It has been pointed out previously in this paper how a clipped may be distinguished from an unclipped fur,

[9] L. A. Hausman, "The Pigment Granules of Human Head Hair, A Comparative Racial Study," *Am. Jour. Phys. Anthrop.*, 12: 273, No. 2, October–December, 1928.

and what the microscope tells us about the reason for the superior durability of the latter. A glance at Fig. 18 will show how a microscopic comparison of cuticular scales and medullas can help in identifying an unknown hair used in furs or fabrics.

A hair may be clipped and dyed and its cuticular scales may even be altered by corrosive reagents, but the medullary column, or at least elements of it, remain the same, as do also the pigment granules in their characteristic forms and patterns. These structures are of the highest diagnostic value. In Fig. 8, 3, note how the genuine otter and nutria hairs (taken from two neck pieces) give up at once the secrets of their origin. Yet both furs were bought for genuine otter. Note that the hair shafts differ not only in diameter but also in granulation and in the characters of their medullas. Their scales likewise (here not shown, since the hair shafts were cleared in oils) differ, and would have revealed this difference under proper treatment.

It must be remembered, however, in all hair shaft comparison examinations, that the same parts of the shafts under comparison must be used, since pigmentation, medulla and scale characters may differ from end to end of the hairs. Likewise it must be made certain that the hairs were taken from the same general regions of the bodies, for in some cases regional differences exist, as has been shown, for example, with respect to the duckbill (*Ornithorhynchus anatinus*).[3]

In making comparisons of minute structures, the comparison ocular proves to be the *sine qua non* of microscopical appliances. This is an optical device, attachable to two identical microscopes, as shown in Fig. 19, below, which gives one such a view of the objects under examination as is shown in Fig. 8, 3, where the two objects are brought close together, in the same field of vision, magnified to the same extent and lighted in the same way. The addition of a micrometer to the eyepiece makes possible accurate measurements also. Many secrets hidden from the unaided eye have been made to yield themselves up under this sort of inescapable scrutiny.

FIG. 19. ENSEMBLE OF APPARATUS FOR THE EXAMINATION OF HAIR SHAFTS BY DICHROMATIC ILLUMINATION. *Above: A*, LAMP DELIVERING THROUGH ITS RED GLASS SCREEN, THE RED LIGHT *r* FOCUSED UPON THE OBJECT THROUGH A BULL'S EYE CONDENSER. *B*, LAMP DELIVERING THROUGH ITS SCREEN GREEN LIGHT, *g*, WHICH IS THROWN UP THROUGH THE TRANSPARENT PARTS OF THE OBJECT BY THE SUBSTAGE MIRROR. *M*, OCULAR MICROMETER. *Below:* APPARATUS FOR COMPARISON OCULAR EXAMINATION OF HAIR SHAFTS WHERE CLOSE COMPARISON OF KNOWN AND UNKNOWN SAMPLES IS NECESSARY. *C*, COMPARISON OCULAR YOKE. *E*, EYE LENS OF OCULAR GIVING SUCH AN IMAGE AS THE ONE SHOWN IN FIG. 8, 3.

For the examination of cuticular scale forms and medullas simultane-

ously, as well as for the study of minute sculpturings on the scales themselves, the writer has devised the assemblage of apparatus shown in Fig. 19, above. By means of this a hair shaft under examination is illuminated at the same time with beams of light of two colors. By employing this sort of dichromatic illumination it is possible to invest some structures in the object with one color and other structures with its complementary color, and thus bring out strikingly by contrast the relationships of the two. Thus, as in Fig. 19, above, the opaque parts of the object on the stage would be viewed by reflected red light, whereas the transparent parts of the same object would be seen by transmitted green light. The micrographs in Fig. 18 were drawn as viewed under dichromatic illumination of this sort.

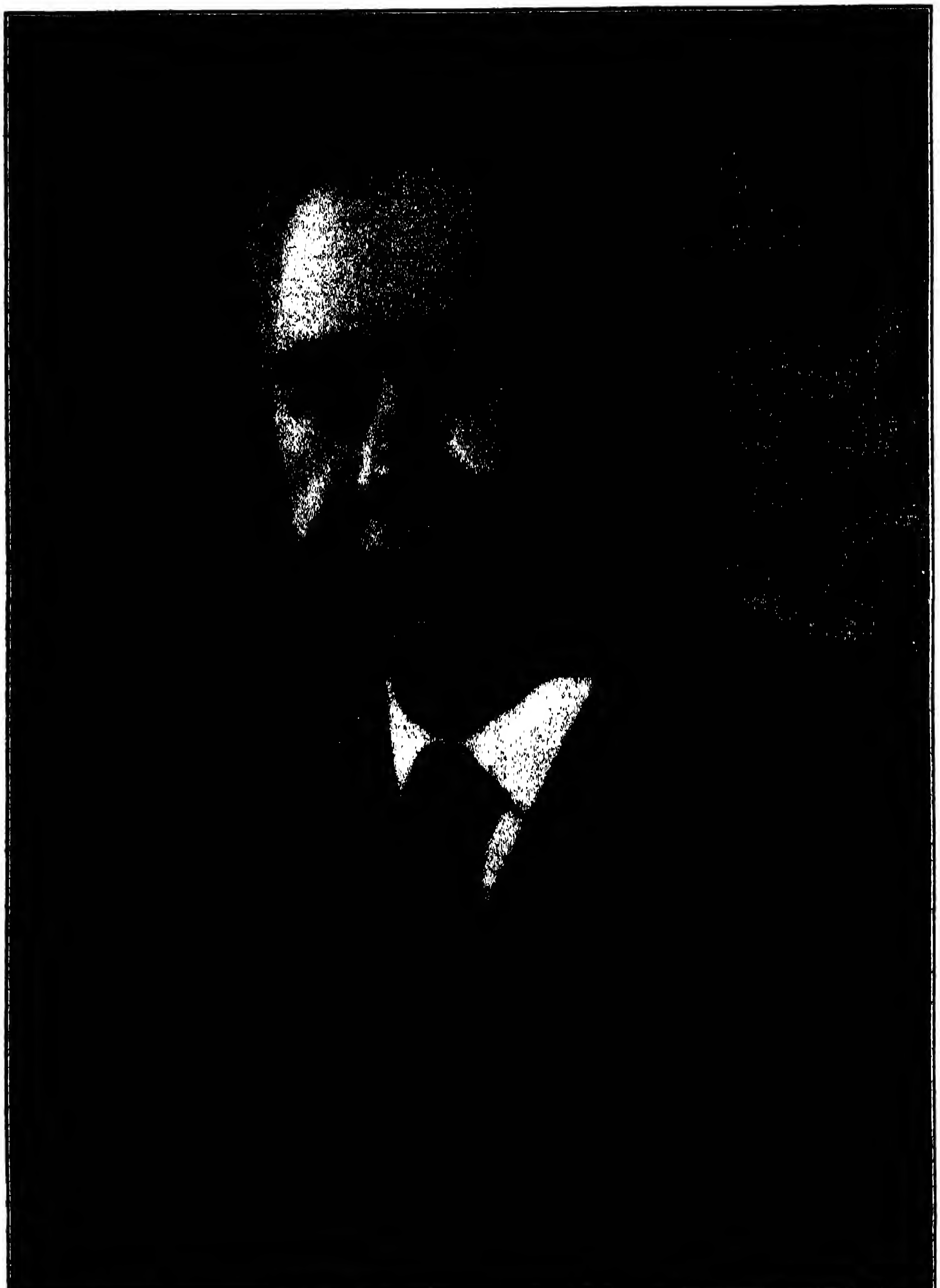
With respect to human head hair under the microscope, the writer believes, in the light of recent studies of the hair shafts, that it is not possible to determine (from the status of the microscopic elements of the hair shaft) the age, sex or race, since these hair shaft elements are so variable in respect to any one individual and since, moreover, what stability of relationships they do show is associated with hair shaft diameter.[10] This with regard to hairs from normal follicles, and not from follicles diseased or abnormal. When it comes to the question of identifying human hairs, having both known and unknown samples with which to make comparisons of the medullas, cuticular scales, pigment granules, cortical cells, status of diffuse stain and shaft diameters, or unusual modifications (perhaps hereditary, and hence diagnostic) of any of these, then the matter is quite different. But even here it must be possible to make comparative studies between the same portions of the hair shafts, and if one has only fragments of hairs it must be known what parts of the complete hair shaft these represent. Sometimes the microscope may help to settle this question.

The technique of preparing hair shafts for the study of their various elements has been described in earlier papers. Fortunately most hair shafts (those not too heavily invested with pigments) are transparent or nearly so, and this simplifies their examination.

Some of the interesting applications of trichology which have been made in the writer's laboratory are: (1) the study of prehistoric South American Indian grave fabrics, in the hope that it would aid in the fixing of a historical date; (2) the study of cave remains of an early North American Indian occupation, in which hairs of the bison were found, which finding extended our knowledge of the range of this species; (3) a similar study which gave new data concerning the range of the black bear; (4) the examination of a man-killing mountain lion's stomach contents in which human hair was present; (5) the comparison of human hairs in certain legal proceedings; (6) the comparison of hairs from furs to determine whether or not these were correctly named; (7) the examination of hairs from a large chicken farm enclosure, to help to fix the blame upon the mammal culprit which was depredating the stock, and hence to indicate the proper trapping methods to be used against him.

It is not always possible, however, for the microscopist to arrive at a satisfactory conclusion, for the microscope reveals a great deal, in that world invisible to our unassisted vision, which is puzzling to us mortals who pass most of our time in looking out upon things in the gross.

[10] The examination of hair in masses may tell much, as can be seen from the literature.



VICTOR CLARENCE VAUGHAN

THE PROGRESS OF SCIENCE

VICTOR CLARENCE VAUGHAN

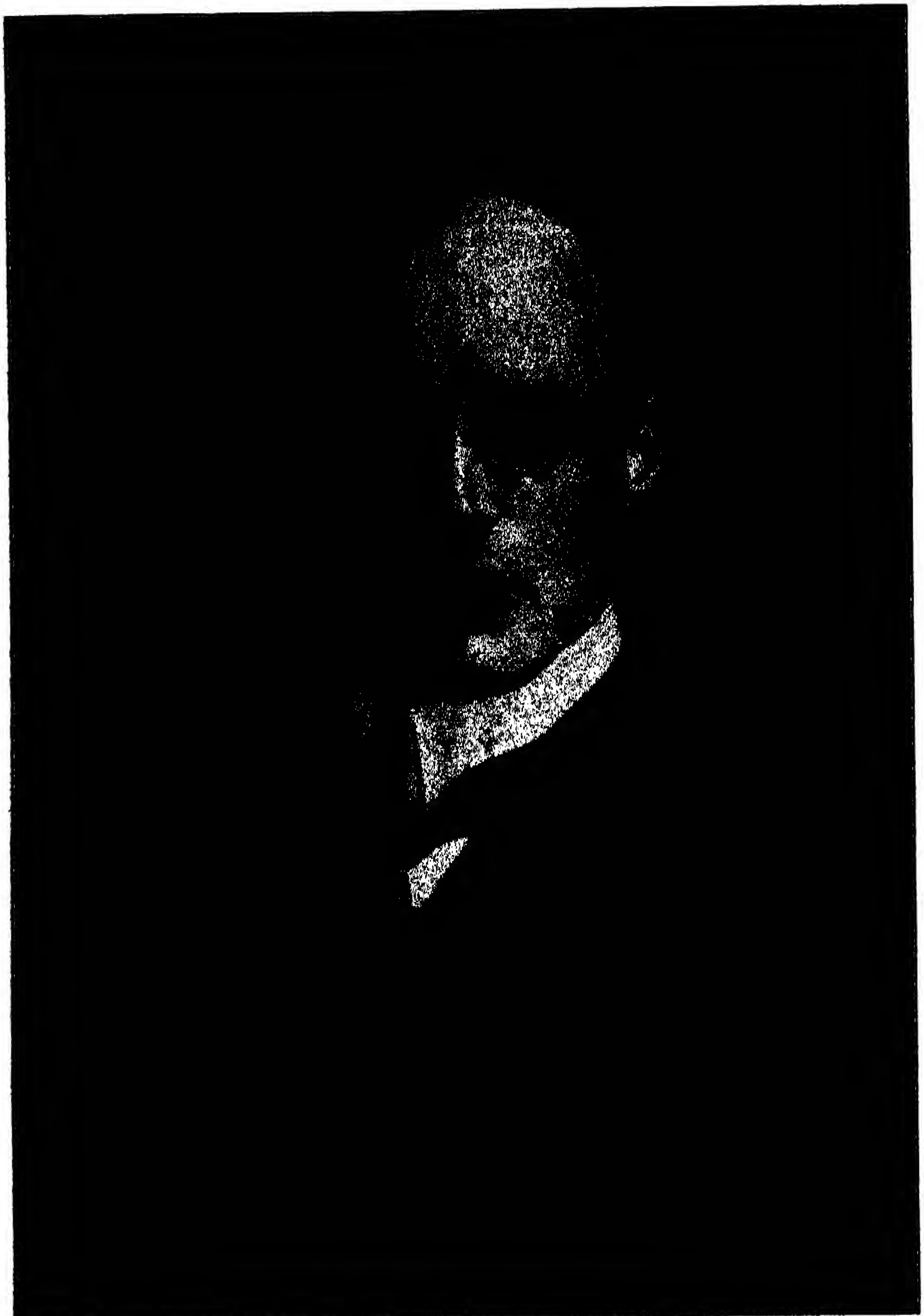
The death of Victor Clarence Vaughan has deprived American medicine and public health of a great leader. He was born on October 27, 1851, at Mount Airy, Missouri, and began his teaching connection with the University of Michigan in 1875, as assistant in the chemical laboratory. In 1879 he became lecturer and in 1880 assistant professor of medical chemistry, and in 1883 he was advanced to the professorship. In 1887 he became professor of hygiene and physiological chemistry and director of the newly established hygienic laboratory. To these duties he added, in 1891, that of dean of the medical school. He held this chair and the deanship until 1921 when he retired as emeritus professor.

Retirement from the university did not close his activities. For several years, as chairman of the Medical Division of the National Research Council, he resided in Washington. It was there he wrote his splendid work, in two volumes, on "Epidemiology and Public Health," and in 1926 he produced his living autobiography "A Doctor's Memories." In the fall of that year, with Mrs. Vaughan, he went as delegate to the Medical Congress in the Orient, visiting China, Japan and the Philippines. On his return in the spring of 1927 he suffered an attack from which he never fully recovered.

Dr. Vaughan was president of the Association of American Physicians in 1908 and of the American Medical Association in 1914. He was a member of the National Academy of Sciences and the American Philosophical Society. As an editor he founded the *Physician and Surgeon*, the *Journal of Laboratory and Clinical Medicine*, and served as the first editor of *Hygeia*. During his thirty years of service on the Michigan State Board of Health he did much to spread the growing knowledge of sanitation and public health.

Dr. Vaughan's investigations covered many fields. At first, the examination of water supplies claimed much attention, and in this connection he devised what he termed "the Michigan method" of analysis which made use of the experimental animal as a means of detecting harmful bacteria. His studies on food poisonings were likewise extensive and thorough. He sought the explanation of the germicidal action of normal serum and found it in the complex chemical constituent nuclein. Even more important were his studies upon the nature of the bacterial poisons or toxins. He devised an ingenious "tank" method for growing pathogenic organisms in mass quantities in order to obtain a sufficient amount of the cells for the purpose of studying the bacterial proteins which he was able to break up into two portions. one toxic and the other non-toxic. He utilized these results in formulating a valuable theory bearing upon the nature of hypersensitiveness and of fevers. As an earnest and enthusiastic investigator Dr. Vaughan had few equals. His extraordinary capacity for writing found expression in more than two hundred publications, not including his more pretentious works, on physiological chemistry, on ptomaines and leucomaines, on cellular toxins, on protein split products, on infection and immunity and on epidemiology.

At the outbreak of the Spanish War Dr. Vaughan volunteered his services and saw active service at Santiago where he contracted yellow fever. The most deplorable fact in connection with that war was the outbreak of serious disease among the troops in the different concentration camps. Laboratory methods were non-existent in the camps, and the



PROFESSOR OWEN WILLANS RICHARDSON

prevailing disease was called indigestion, malaria or typho-malaria, rarely by its true name—typhoid fever. At the close of the war a commission, consisting of Majors Walter Reed, V. C. Vaughan and E. O. Shakespeare, was appointed to investigate the outbreak. The final report of that commission was prepared by Dr. Vaughan, the only surviving member. It was a classical contribution to the epidemiology of typhoid fever. Upon our entry into the late war, Dr. Vaughan was again called upon to give his services. As one of the board in charge of the communicable diseases in our camps, he served with ability and distinction, receiving the rank of colonel, the Distinguished Service medal and the decoration of the French Legion of Honor. More recently he was the recipient of the Kober medal. His work during the two wars brought him full recognition as a leading epidemiologist. As a member of the National Research Council which came into being at the request of President Wilson, Dr. Vaughan participated in the work of that body by his wise counsel and his vast experience.

It is as an instructive and inspiring teacher that Dr. Vaughan will be remembered by the thousands of students who had the opportunity and privilege of listening to him. He freely drew upon his experiences in life and by his masterly presentation made the lectures interesting and forcible.

Unquestionably the greatest service which he rendered to the cause of medical education came during his tenure of the deanship. At the time that he entered this office the new laboratory methods of instruction were just coming into their own. With his clear foresight he recognized the importance of having productive scientific men upon the faculty, and it was this fact which enabled him to get together men of outstanding ability, thus placing the medical school of the university in the front rank of the schools in the country.

Dr. Vaughan's interest in the investigations of his colleagues was not less than that in his own researches. He lived, so to speak, in the laboratory and was never so happy as when a new fact or result rewarded his work. He loved his fellow men and freely gave of his time and energy. As a scientist and educator he was among the first. He has left an enduring impress in both fields. A great leader, a constructive thinker and a broad idealist is gone.

FREDERICK G. NOVY

PROFESSOR OWEN WILLANS RICHARDSON, NOBEL LAUREATE

THE award of the 1928 Nobel Prize in physics to Professor Owen Willans Richardson, of King's College, London, is a matter of particular interest and gratification to Americans because a considerable part of the work for which the award has been made was done at Princeton during Professor Richardson's residence of more than six years in this country, and also because of the benign influence which Professor Richardson's presence with us has had upon the course of physical research on this side of the Atlantic. It is appropriate in these circumstances to make this American episode in Professor Richardson's life the central theme of this brief biographical note concerning him.

In the summer of 1906 the late Dean Henry B. Fine, of Princeton University, visited Sir J. J. Thomson (then Professor Thomson), of Cambridge University, and asked him to recommend, from the large group of brilliant investigators then working under his direction in the Cavendish Laboratory, a candidate for a research professorship in physics which had been recently established at Princeton. An attempt was to be made to transplant from the ferment of physical

research, then so active in the Cavendish Laboratory, a culture which, it was hoped, would engender a similar ferment in America. The "culture" selected and recommended by Professor Thomson was the subject of this note.

Professor Richardson, then a fellow of Trinity College, had at that time worked for some years in the Cavendish Laboratory and had devoted himself particularly to an investigation of the emission of electricity (electrons) from hot bodies (glowing filaments). In the prosecution of this investigation he had distinguished himself by his exceptional ability as both an experimental and a theoretical physicist. He had discovered how the rate of emission from a hot body varies with the body's temperature, had given mathematical expression to this relation—thenceforth to be known as Richardson's Law—and had put forth a theory of the phenomenon in which the emission of electrons from an incandescent filament was pictured as similar to the evaporation of atoms from a liquid on solid surface. He had introduced into physics the important concept of a "work function," a measure of the work required to detach an electron from a metal, as a necessary feature of this theory. These things he had accomplished at the age of 27, and at a time when experimental facilities for this kind of work were much less adequate than they are to-day. Professor Thomson paid a great compliment to Princeton University in recommending such a man for the newly established professorship.

Professor Richardson arrived in Princeton in the autumn of 1906 accompanied by his bride of a few months, the sister of his friend and colleague at Cambridge, Professor Harold A. Wilson, now of Rice Institute; and was followed shortly by his own sister, now the wife of Professor Oswald Veblen, of Princeton. Sir James Jeans (then Professor Jeans) had come to Princeton a year earlier, and during the academic year 1906–07 graduate students at Princeton had the benefit of contact with both these eminent English physicists.

At Princeton, Professor Richardson pressed forward with great vigor further investigations in "thermionics," as he named his chosen field. Alone or in collaboration with others, he made at Princeton the first reliable observations upon the so-called "cooling effect," which is the analogue in thermionics of the cooling by vaporization with which we are familiar in the case of liquids. In collaboration with Professor H. L. Cooke, he made the first observations upon the reverse effect, the heating of filaments through the absorption of electrons. These experiments confirmed the theory which was serving as a guide to the investigations, and yielded data from which the values of thermionic work functions could be computed. The theory was further confirmed by the demonstration that the electrons leaving a hot body have a Maxwellian distribution of velocities, and that their mean kinetic energy is the same as that of an assemblage of gas molecules at the same temperature. He investigated also the emission of positive ions from metallic filaments and from salts. On the theoretical side he elaborated the theory of thermionic emission to the greatest generality consistent with the principles of thermodynamics.

While thermionics occupied the focus of Professor Richardson's attention during this period, his activities were by no means restricted to this field. In addition he carried out or directed investigations in radioactivity and in X-ray phenomena, and especially important ones in photoelectricity. In these latter he impressed on physicists the importance of contact differences of potential in experiments of this kind. His theoretical interests also were diversified; we

find among his papers contributions on the theory of magnetism and on the structure of the ether. The total number of papers bearing Professor Richardson's name as sole or joint author and published during these six years is no less than thirty-four—a surprisingly great number in any circumstance, but particularly so when it is considered that during the first two of these years physics at Princeton was lodged in the ancient and poorly equipped Science Building; the Palmer Laboratory was not completed until 1908.

Among Professor Richardson's students during these years were Professor A. H. Compton, of the University of Chicago, also a Nobel laureate; Professor K. T. Compton, the able successor of Professor Richardson as director of research in physics at Princeton; Dr. C. J. Davisson, of the Bell Telephone Laboratories, New York, whose wife is another of Professor Richardson's sisters; Professor A. G. Shenstone, of Princeton University, and Professor K. K. Smith, of Northwestern University.

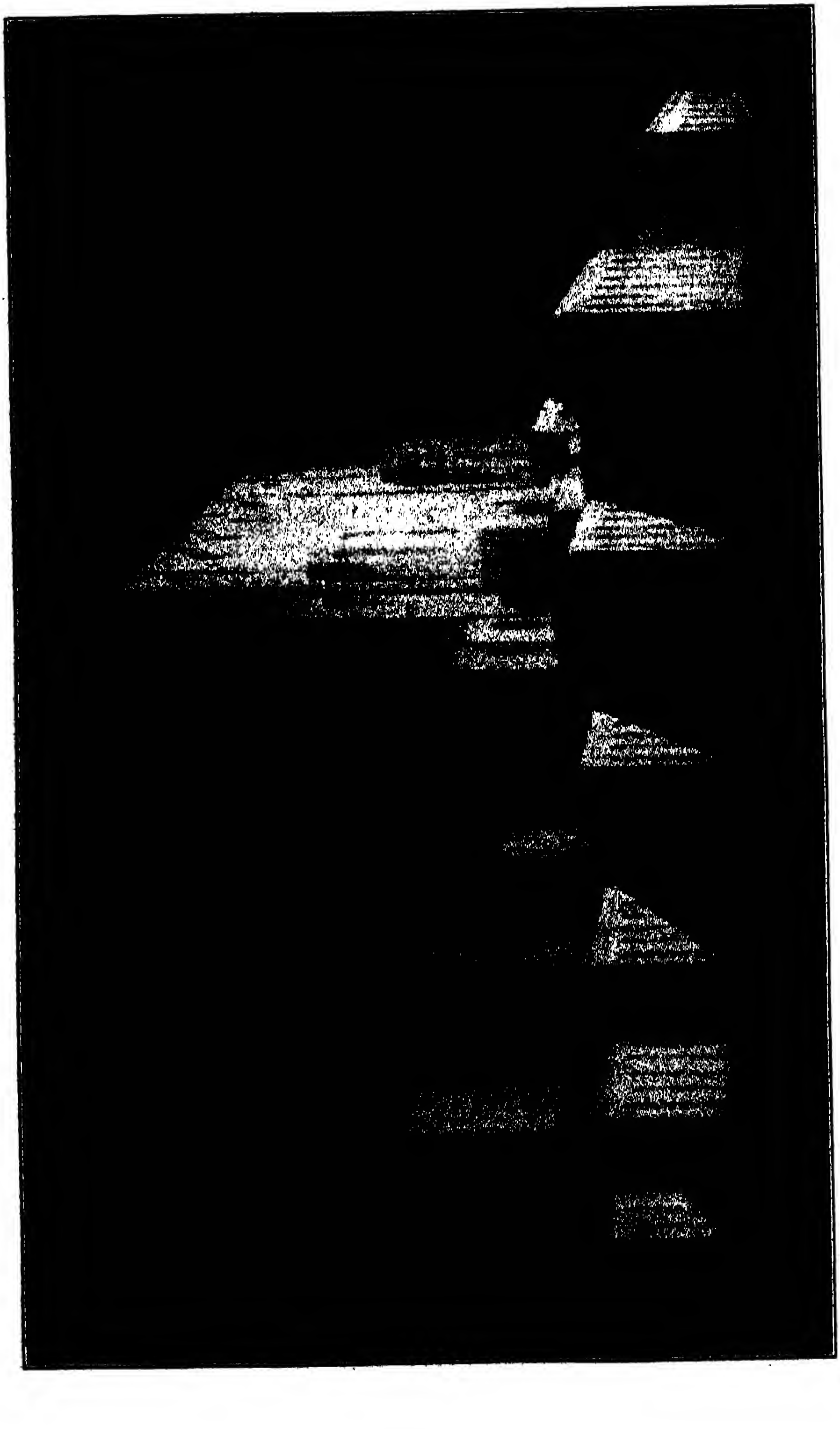
Professor Richardson is remarkably conversant with all the great volume of experimental and theoretical work which has followed upon the discovery of X-rays and the isolation of the electron. His book "The Electron Theory of Matter," written at Princeton and published in 1914, is the most comprehensive summary we have of this newer physics, as of that date.

Professor Richardson was an active and highly valued participant in the meetings of the American Physical Society, and spoke often before other scientific bodies as well. The American Philosophical Society elected him to honorary membership; and it was also during his Princeton days that he became a Fellow of the Royal Society of London.

The conditions under which Professor Richardson worked at Princeton, particularly after 1908, were in many respects ideal, and yet it can not be said that he was ever completely happy in the American environment. He disliked the hot New Jersey summers which interrupted his work and drove him and his family from Princeton to the coast of Maine. But quite apart from climatic considerations he longed to return to England, and did so when he was offered the Wheatstone professorship of physics at King's College, London. He returned to England with his wife and three children in December, 1913. His leaving was a great loss to physics in America and a matter of keen regret to the many friends he and his family had made in Princeton and elsewhere in America; but the aim which Dean Fine had in view had been attained; the culture had thriven. A center of research into the newer problems of physics had been established at Princeton. To-day it is one of the most important in the country.

Half a year after Professor Richardson's return to England, Europe was plunged into the world war. His activities, like those of nearly all other European physicists, were deflected from their accustomed channels. During the war he was attached to the British Admiralty to which he rendered valuable service, and yet during this period he managed to bring out a second and revised edition of his "Electron Theory of Matter," and the first edition of his "Emission of Electricity from Hot Bodies." A second edition of this latter treatise was published in 1921.

Professor Richardson's work in thermionics for which he received the Nobel Prize may be said to have ended with his stay at Princeton. Since the war his interests have centered in other problems, in the emission of electrons during chemical reaction, in soft X-rays, in photoelectricity and particularly in spectroscopy. In this last named field he has devoted himself for some years to the



—*From a photograph of the architect's drawings*

THE NEW YORK HOSPITAL-CORNELL MEDICAL COLLEGE BUILDINGS

ordering and interpreting of the complicated band spectra of hydrogen. In this field, as in that of thermionics, he has made himself preeminent.

In 1924, Professor Richardson resigned the Wheatstone professorship to accept one of the three newly established Yarrow Research Professorships of the Royal Society. His connection with King's College was not, however, severed; he is still the director of research in physics in that institution.

In 1920, Professor Richardson was granted the Hughes Medal by the Royal Society, for his work in thermionics. The following year he served as president of Section A of the British Association, and from 1926 to 1928 he was president of the Physical Society of London. To these and his previous honors and preferments is now added the crowning one bestowed upon him by the Swedish Academy. It is a signal honor, well earned and richly deserved.

THE NEW YORK HOSPITAL–CORNELL MEDICAL COLLEGE ASSOCIATION

MATERIAL prosperity has always carried with it an implied obligation to advance the scientific, social, cultural and artistic standards. One of the most promising indications that America is recognizing this obligation and is preparing to meet it in keeping with her great means is the new medical center now under construction by the New York Hospital-Cornell Medical College Association.

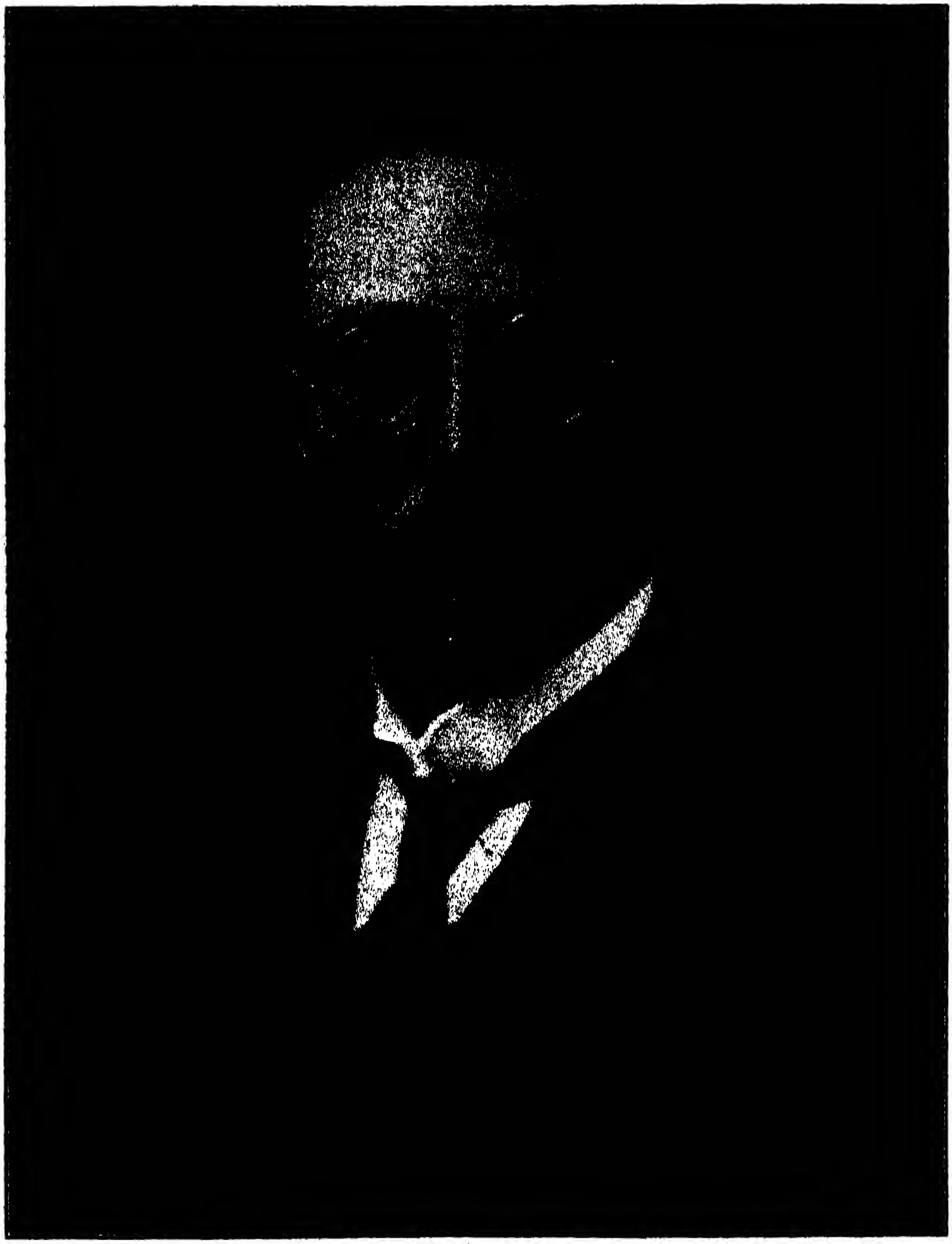
This project bids fair to become one of the most far-reaching and important undertakings for the advancement of medical science and of human welfare. It will bring together, under unified control, one of the nation's foremost hospitals, with a record of a century and a half of distinguished service, and one of its leading schools of medicine.

The buildings which are now being erected by the Association, on a site covering three square blocks along the East River in New York City north of Sixty-eighth Street, are designed to afford complete coordination of all activities in medical education, research and care of the sick. In the early stages of this development, its activities are manifest chiefly in terms of structure and facilities, but it is realized by the Association that the true importance of these things lies not in themselves, but in the opportunities they afford to distinguished medical scientists and practitioners for the advancement of science and practice in medicine.

In the central section of the development will rise the main building of the hospital, twenty-four floors in height. On the West, it will be flanked by the laboratories of the medical sciences, five in number, extending for two blocks along York Avenue. Along the river, and connected with the main hospital building, are to be three special clinical institutes. One will be devoted to maternity work and will take over the service of the Lying-In Hospital. Another will be a psychiatric institute, for which Payne Whitney, whose gifts in great measure made the whole project possible, made special provision in his will. The third will be a pediatric institute, devoted to research and the treatment of children's diseases.

Although it has no formal connection with the new center, the presence of the Rockefeller Institute for Medical Research as its immediate neighbor on the South is significant, as it will bring into close association men in both institutions who are working on allied problems in medical science.

From the standpoint of medical research, the center will afford unusual opportunities for cooperative investiga-



—*Bacrach*

PROFESSOR AUGUST KROGH

WHO BY SPECIAL INVITATION GAVE THE PRINCIPAL ADDRESS AT THE INTERNATIONAL CONGRESS OF PHYSIOLOGY. DR. KROGH, WHO IS DIRECTOR OF THE ZOOPHYSIOLOGICAL LABORATORY OF THE UNIVERSITY OF COPENHAGEN, WAS AWARDED A NOBEL PRIZE FOR HIS WORK ON THE PHYSIOLOGY OF THE CAPILLARIES.

tions bringing together in daily contact men who are working in almost every field of medicine.

The center will provide facilities for the treatment of 1,000 bed patients and approximately the same number of out-patients daily. The teaching, research and hospital staff, undergraduate and graduate students, and nurses and employees, will number from 1,500 to 2,000 persons.

Between Seventieth and Seventy-first Streets, the Association is building a nurses' home to house 500 student and graduate nurses, an employees' dormitory, and a service building garage and power plant designed to serve the entire center.

THE DR. WALTER B. JAMES MEMORIAL LABORATORY FOR BIOPHYSICS

A NEW laboratory is being completed for research in biophysics at the Biological Laboratory of the Long Island Biological Association at Cold Spring Harbor. The completion of this building marks not only a step forward by that laboratory, but gives indication of the strength of a new viewpoint which will doubtless find expression in an increasing number of institutions.

At Cold Spring Harbor the laboratory has been established from the point of view that it shall be a real physical laboratory, equipped with all the facilities of a modern physical institute, for work with problems in biology. The primary aim of the laboratory is therefore to develop physical apparatus and methods of value to biology and to carry on research in those fields in physics in which work is required for the purposes of biology.

As a secondary aim, the laboratory will place at the disposal of visiting biologists various physical apparatus developed at the laboratory or such standard physical apparatus as is available. It is considered that Cold Spring Harbor provides an ideal place for such a laboratory by giving an opportunity for first-hand acquaintance with such apparatus to the large number of investigators from universities and medical schools throughout the country who are in residence at the Biological Laboratory during the summer. It is expected, in this way, that the equipment and findings of the laboratory will be of immediate and unusual value to biologists at large.

The laboratory itself, of which a photograph is reproduced herewith, has been planned and constructed with special attention to safety, and to the control of temperature, vibration and noise. It is one story in height and of simple utilitarian architecture. It includes an X-ray laboratory equipped with a 10 K.W. 140 K.V., kenotron-rectified X-ray generating unit, installation for pumping X-ray tubes and other kinds of vacuum tubes, apparatus for measuring X-rays in the new international r-unit; a laboratory equipped for work with high frequency electric currents; a chemical laboratory equipped with a number of special apparatus especially designed for a study of the chemical action of X-rays, an apparatus for electrometric titration, apparatus for analysis of gases, a spectrophotometer; a mechanics shop with shop equipment and tools for precision work, a carpenter shop and a glass-blowers' shop. There are also a cold room, a photographic room, a filing room and a small library. Provision has been made for the addition of a second story when needed.

The laboratory has been named the Dr. Walter B. James Memorial Laboratory in honor of Dr. James who was for many years an officer of the laboratory and who was president of the Long Island Biological Association at the time of his death. The building was given by Mrs. James in recognition of Dr. James's sustained and reasoned interest in the work of the Biological Laboratory.

THE DR. WALTER B. JAMES MEMORIAL LABORATORY

The laboratory for biophysics is under the immediate charge of Dr. Hugo Fricke, who was appointed to the staff of the Biological Laboratory one year ago. Previously he had been director of the department of biophysics of the Cleveland Clinic Foundation. The technical staff includes an instrument-maker, a radio engineer and a glass-blower. Dr. E. Saxl, of Vienna, is collaborating in research on the electrical capacity and conductivity of biological cells and systems, and Messrs. R. W. Asmussen and A. Hempel-Hansen, of the University of Copenhagen, are cooperating in studies of the chemical action of X-rays.

THE SCIENTIFIC MONTHLY

APRIL, 1930

THE SOCIAL SCIENCES TO-DAY

PRESIDENTIAL ADDRESSES BEFORE THE AMERICAN ECONOMIC ASSOCIATION, THE AMERICAN STATISTICAL ASSOCIATION AND THE AMERICAN SOCIOLOGICAL SOCIETY AT A JOINT MEETING IN WASHINGTON, D. C. DECEMBER 28, 1929

HISTORICAL RECORDS

By Dr. EDWIN F. GAY

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Economic history belongs to both history and economics; it seeks to be helpful to both but to dominate neither. By its own relationship to these two disciplines it illustrates the growing cooperation of the social sciences, of which a specific recent example is the proposed international investigation of price history. But economic history suffers from the defect of all history, the imperfect character of the historical record and the various biases in its interpretation. The record tends to preserve evidence of institutional forms, while processes of change in the ideas which underlie institutions are much more evanescent. The increasing minuteness of modern social recording, especially its quantitative measurements, and the new zeal in collecting business documents will help to complete the record for the future economic historian. The demand for a great amplification of statistical records is a part of the contemporary triangulation, now proceeding, upon which to base a new development of social controls.

If the shoemaker is well advised to stick to his last, the learned professions, which in our day have inherited much of the medieval craftsman's ethics, may occasionally obey this precept. I may properly, therefore, on this occasion make some random observations upon historical records, the raw materials of my craft. Practically all the great variety of records used by historians in general are also necessary to the economic historian, and his technique in the use of these records is that common to all historical criticism. But this branch of history has chosen for its field that longitudinal section through the great mass of material which is concerned primarily with economic activities and relationships. Since the economic historian is vitally interested in the past development of economic institutions and processes and their bearing on present problems, he must also regard his work as a branch of the science of economics. Fundamentally important, however, as the economic factor appears to him, he does not regard it as the one determining factor in human affairs past or present. Man does not live by bread alone. And no active group of economic historians is to-day making any such claim for the predominance of this specialism as did the German "historical school," from Roscher and Hildebrand to Schmoller.

The leaders of the "historical school" inevitably had to err by excess of zeal in

order to make their contribution in establishing the principle of relativity; no longer can any one proclaim, as did the Manchesterists of the mid-nineteenth century, that free trade is a doctrine eternally valid and universal in its application. The economic historian of our time realizes that the problems, economic and social, which confront us are much too complex and difficult to be understood by any one-sided approach. The cooperation of every usable method is required; and the critical method of history, emphasizing sequential relationships, is one among several essential tools. Like the physical sciences in their modern interlocking, the social sciences are borrowing from one another both tools and workers.

The historical investigation of prices now being launched, with the aid of a substantial grant from the Rockefeller Foundation, involves such collaboration. This history of prices, including wages, from the earliest fairly continuous records to that point, differing of course in each country studied, where the various price series may be linked with those in current statistical use, is to be carried on by scholars from England, France, Germany, Austria, Spain and the United States, under the chairmanship of Sir William Beveridge. Within the next five years, the establishment of long measures of price-changes in these countries may be expected. It is hoped to document these more fully and make them more reliable than was possible with those produced by such pioneers, working single-handed, as Thorold Rogers, d'Avenel or Wiebe. Price records will be sought which are continuous for one locality or for homogeneous market areas. Basic price series thus set up may of course be combined to show larger regional or national averages, but the totals will not conceal the divergent weightings of different regional price levels. A uniform general plan will be followed, including a careful reduction of the numerous local variations in weights, measures and coinage, so that some approximation may be made to international comparisons—a procedure of especial importance, for instance, in studying the geographical dispersion of price-changes as the great wave of the sixteenth century price revolution spread from Spain over western Europe. By separating and comparing the various groups of prices, new light may be cast on long-time changes in the behavior of prices and on the effect of such changes upon the attitudes and positions of great social groups of the population at successive periods. The investigation will require not only the association of scholars from the several nations selected, but also the close cooperation of a number of workers in different fields, especially of historians, archivists, economists and statisticians. When once this relatively dependable causeway has been thrown over the morasses of earlier economic history, we shall have greatly lengthened, though on a narrow front, our statistical base-line, now so short.

But happy as are the economic historians over this opportunity for the improvement of their one possible long statistical measure, they realize fully how imperfect their best efforts must leave it, for the causeway will be very narrow, and at places badly broken. Even with the cautious piecing together of much more material than has hitherto been available, serious gaps and deficiencies in the historical record must inevitably remain.

Although always aware of the serious deficiencies in all the records upon which he is dependent, the historian, by reason of the requirements of continuous narrative, usually fails to convey to the reader the full meaning of this imperfection. Absence or scarcity of records, often at vital points and over considerable spaces of time, is the most obvious and distressing of handicaps. But continuously baffling is the qualitative in-

adequacy of the material, its inherent and shifting biases, even when, as in the most recent centuries of history, the volume of records increases enormously. The rise of modern states and of centralized governments resulted in an immense increase of paper-work and the gradual organization of state archives, where there are housed and prepared for use great collections of political, administrative and judicial documents. The invention of the printing-press brought a flood of books and pamphlets, and by its help in making men literate brought forth new stacks of writings, private in character, to bless and to harass the historian. To curse with Carlyle this Dryasdust accumulation or to wish that the multitude of men had remained voiceless is inadmissible. Instead, the crushing task is divided and subdivided by shorter periods and narrower topics, but the increasing division of labor has not lessened the most crucial difficulties.

This very defectiveness of the raw material of his craft has largely determined and limited the method and aim of the historian. Historical technique, higher criticism, interpretation amounting to interpolation—what are they in the main but methods and practices of filling gaps and correcting biases? History has sometimes been severed from the other social sciences by limiting it to the peculiar function of describing the unique occurrence. Some go so far as to assert that this function forever debars it from any attempt at the comparisons, classifications and generalizations which characterize a science. May it not be truer to say that the consciousness of defective material and the consequent hypertrophy of critical talent have tended at times to check the human craving for synthesis? The wary historian, taught and teaching the dangers of historical analogies, has tried to limit his professional risks; but he is increasingly minimizing those risks. In our modern historical studies a rough series of transitional forms may be traced between the two poles of research, between the narrative of the individual sequence, especially characteristic of political history, and the emerging science which essays, by the comparative method, the discovery of the laws or continuities of group action. There must be and must remain the detailed description of the single specimen, the individual sequence. The art of historical narrative will not die. But as the records, with the aid of all the kindred social sciences, become more adequate and their interpretation more penetrating, history, or rather some branches of the craft, may approximate a historical sociology. The interdependence of the sciences is already exhibited in the use which the social historians, as well as the political scientists, are beginning to make of statistics, or at least in the demand for training which will enable them to check quantitatively their descriptive studies.

L. P. Namier's recent book on the structure of English politics at the accession of George III is an example of this use of statistics. Despairing of gaining fresh insights from the accustomed sources, such as the gouty *bon mots* of Horace Walpole's letters or the acrid outcries against the nabobs or the mutual diatribes of parties against the corruption practiced by opponents, Mr. Namier undertook the compilation of a card index containing the fullest details, especially from local records, family and local correspondence, concerning every member of the House of Commons from 1760 to 1783. After years of this minute inquiry, he has published this notable initial study. His text is shot through with numerical tests of such problems as the extent of aristocratic influence upon the representative system, or how much voting power was exerted by the new wealthy class, or the weight of the crown and administration in elections or the supposedly prevalent corruption of the electorate.

As each generation thus rewrites its history of the past—a proceeding necessary because of defective records and because of the shifts in selective interest and in the configuration of contemporary biases—some of the gaps in the record become partially filled. But no amount of research or tenable conjecture can eke out the most serious silences of our sources. This is particularly true in certain fields of economic history. Such institutional structures as the open field system, the craft guilds or the factory, which have left behind them a record of customary regulations or external legislation, have, like the skeletal forms of zoological species, deposited their fossils in the historical strata. But the more dynamic elements, like the vital organs and the nervous system, have tended to disappear. We can with considerable accuracy reconstruct these economic institutions in what we may term their skeletal form; but how and why they came into being, what animating forces actuated them in their prime and gradually ebbed in their decline, are questions not easy to answer from our materials.

Take, for a simple instance, the flow of trade as a formative influence on industrial institutions. Of foreign commerce, its agents and carriers and its extent, we have, for the pre-statistical period, some fragments of information, but for local or domestic trade the material is almost hopelessly inadequate. Very difficult and elusive is also the study of past changes in the standards of living. The record of economic history is therefore unevenly weighted, tempting us to stress successive stages of production and to neglect the dynamic factors of distribution and consumption.[1] Even our current statistical record is notably weak on domestic trade, and the analysis, statistical and other, of the assumptions underlying the demand curve is inadequate. We shall have in 1930 the first national enumeration of the agencies and amounts of market distribution, and this will be warmly welcomed by economists for the help it may give on this much-needed point.

But why should a busy world produce statistics for the delight of economists? We are told that economists are a voracious species, greedy for figures, only to be satisfied when census-takers and social psychologists stand beside the remaining third of the working population. By implication, we should be satisfied with the existing notable increase in our equipment for economic and social measurement since the World War. Nearly all the departments of the federal government are busy turning out statistical tables in growing volume, but as yet too little coordinated.

Numerous state, regional and local agencies are doing likewise. Trade organizations, university research bureaus, independent institutes, private investigators fill the country with questionnaires and statistical publications. And still further plans for quantitative research, nation-wide and local, are constantly emerging. Is not all this more than enough? asks the business man. The economist answers with an emphatic negative. Our modern world stands but at the threshold of the "statistical period" for which the meager but gradu-

[1] Thorold Rogers had a naïve habit of treating his hypotheses as facts. Hewitt's study of medieval Cheshire records has recently shown up this foible. Rogers first expressed doubt regarding Cheshire's medieval salt production, a commodity of prime importance, and thereupon he converted the doubt into a flat denial. This bald assertion was apparently based on the absence of Cheshire salt from the record of price quotations. But Hewitt's researches (*cf.* H. J. Hewitt, "Medieval Cheshire," 1929, pp. 108–112) make it evident that the Cheshire brine springs were continuously worked and that, though the data in regard to distribution are very scanty, the number of recorded salt-houses far exceeded the needs of local consumption. In other words, the strata of the thirteenth and fourteenth centuries show plenty of skeletal forms of production, but the evidence as to the considerable trade which created them was never recorded or has almost vanished.

ally accumulating statistical records of the pre-war century formed merely the initial and preparatory stage. We are far from the saturation point of supply, and the demand is unappeased.

This quite modern craving for exact knowledge of economic and social institutions and processes is a definite symptom of the advent of a new historical era, which was ushered in toward the last quarter of the nineteenth century by a definite reaction against the régime of unfettered, individualistic, secretive competition. Urgent social need, felt a century earlier in western Europe and in the regions within its radiating influence, had unleashed the individual, long straining for free activity, and this release in turn had stimulated the demand for ever more intense production. The world witnessed an unrivaled outburst of industrial energy, an unprecedented movement of migration, an age of unexampled magnitudes and speeds. The spurt of initiative was assisted by a new theory and a resulting policy, in law and economics—rationalistic, hedonistic, individualistic and dogmatic—which, with the clear-cut certitude of a new faith, enforced the destructive but energizing work of liberalism. But, unfolding with an inner logic of growth, out of the older order emerged fresh forces and institutions. Protectionism, with tariffs facing outward and dikes of combination crossing inwardly, restrictionism in its various aspects, including its check on the free flow of immigration, and nationalism in intensified forms—with interceded social cooperative organizations—were among the manifestations of the new spirit. But meantime, with the growing complexity of the social situation, new concepts of relativity, of evolutionary adaptation and of social solidarity were steadily undermining the former certainties of an automatic, mechanical, predestined harmony. The altered pattern of men's thinking, even though, or perhaps because, it was accompanied by a sense of fluidity, has reinforced the dominant demand for stability and social controls.

The need for wisely adapted and therefore more effective controls underlies the craving for more statistical knowledge. If we are to have better social controls, we must have records, many more of them, and more men trained to interpret and to use them. The historians, especially the economic historians, have a peculiar reason for their intense interest in this momentous process of transition going on in our own day. A study of operating social forces in a period of change will yield not strict parallels, but insights and understandings of those earlier operations which have left so impermanent a record. One of the many interesting phenomena which mark such a period as ours is the realignment of public opinion. Who could have foretold in 1890 the change in sentiment which made possible the consolidation provisions of the transportation act of 1920? Yet we can find repeated instances in the past of such almost unconscious refigurement of the public mind, as, for example, the change in opinion in England on the inclosure movement between the sixteenth and the eighteenth centuries. At times, the great changes are initiated and carried on almost unperceived by those who are themselves making them. Common use and wont is one of the greatest enemies of the historical record, for ordinarily those gradual, day-by-day changes in attitude of mind in which multitudes participate are not observed and recorded. New concepts are diffused and slip noiselessly into men's minds; they nestle down beside older alien concepts, often without noticeable jostling; new practices resulting therefrom silently emerge or old ones quietly drop away, until at some point, the preparation becoming far advanced, the new face of the world becomes manifest with apparent sudden-

ness, and the historian, casting about even to set a date to this revolution, discovers another gap in the historical record.

There is strong reason, therefore, at this particular juncture not only to study attentively those hidden things which lie upon the surface of the present, but to collect and preserve the commonplace documents of the immediate past. Already the Business History Society is concerned with the collection, preservation and utilization of business documents, not merely by its Boston headquarters, but by local historical societies generally and especially by university and business school libraries. Such documents as account books, letter files, reports and other records of individual concerns, corporations and trade associations, above all the long-run series which for a time have been heaped in storerooms and then destroyed, should now be preserved, sorted and organized for study. Many of them may be had for the asking, some under pledge of confidence for a certain number of years. What would we not now give for a large accumulation of such material, say from Antwerp of the sixteenth century, or from Lancashire of the eighteenth, to add to such few documents as we possess! Yet we still permit similar records, precious at least to our successors, to be destroyed by hundreds of tons daily.

Towards meeting our own needs and answering our own questions we can do something, and while we can not imagine what questions our successors will put to our time, nevertheless we must build for them as well as for ourselves. It is tempting at times to meditate upon our successors. Perhaps, two or three centuries hence, the highly trained economists in what may at that date correspond to the domestic commerce division of the Bureau of Foreign and Domestic Commerce, at Washington, may be preparing, from the great flow of current information coming daily from all parts of the country, that perpetual inventory of consumable resources, that delicately adjusted economic indicator which will promptly measure and thus help to regulate the fluctuations of business and government enterprise. They may, in their historical section, be reporting on such imperfect but hopeful beginnings as we are making in our statistical laboratories, our surveys of economic and social changes and our presidential conferences. But we can not imagine what kind of ordered world these our successors will be living in, or how far in the rhythm of history the existing tendency to control and stability may be carried. Will they still be discovering new merits in the medieval ideals of the just price and of equality of social opportunity? Or will a reaction have set in against an overdevelopment of the planned national economy and its neo-cameralistic economics?

However uncertain the future, of one thing we may now be fairly sure: as the tides of world history are now moving, each ebb and flow enlarges progressively the knowledge obtainable from the human record. From the imperfections of the social sciences will ultimately emerge more perfect guides to social controls.

MATHEMATICS AND STATISTICS

By Dr. EDWIN B. WILSON

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It is, I believe, the custom for the president, avoiding technicalities in his address, to give the association some general point of view upon that particular branch of theoretical or applied statistics upon which he may consider him-

self reasonably competent to advise. It has seemed to me well to discuss the relation of mathematics to statistics, partly because so many persons behave as though a great deal of mathematical background were essential to a safe and satisfactory practice of statistics and partly because so many others behave in the directly contrary way as though no mathematics at all were necessary and much were harmful. In treating a topic on which behavior is so varied and opinions presumably even more at variance, it must be apparent that I am taking my life in my hands and that if I survive at all it can only be with fewer friends and more enemies.

Mathematics may be either right or wrong. By this I mean that when you add 2 and 5 together you may get 7, which is right, or something else such as -3, which is wrong.

Or, to take a more complicated illustration, if you decide to fit some empirical formula or curve to a set of coordinate data, such as prices and times or populations and times, you may proceed in several ways. First, you may plot the variables and draw in the curve according to your esthetic sense. A curve so fitted can not be either right or wrong, but only a matter of taste. There is no way in which the work can be checked. Of course a dozen persons may be given the same sequence of points and be required each to fit the curve according to his taste; the results of those different fittings may then be compared to determine how much and in what way the solutions differ. I am not averse to this esthetic procedure. When the curve to be fitted is a straight line, it has been found by experiment that the solutions obtained do not, on the average, depart from the "least squares" solution by more than two or three times the probable error of the least squares solution, provided the drawing be made on an adequate scale. In cases where it is not important to check the work and where the precise least squares solution is unnecessary, the graphical method is often the best because the easiest to follow.

There are persons, however, who like to go through the work or force their assistants through the work of a least squares solution even when it is not necessary. And of course there are many cases in which to avoid the work of a least squares solution would be to shirk. One great advantage of such a solution is that it can be checked; it is either right or wrong. Every person who does the work correctly, starting with the same set of data, with the same weights assigned to each point and with the same empirical formula to fit, should get the same answer to that degree of arithmetic accuracy which is justified by the number of places carried in the calculation and without any regard to whether the original data justify carrying so many arithmetic places or not. It is a matter of taste whether one determines to apply least squares; it is also a matter of taste whether he assigns one set of weights or another to the various points, and it is often a matter of taste whether he selects one or another type of empirical formula to be fitted; but once this is all determined, the answer is right or wrong just as $2+5=7$ is right and $2+5=-3$ is wrong—or better, as $\sqrt{2}=1.414$ is right (to four places) and $\sqrt{2}=1.305$ is wrong (even to two places).

Although mathematics may be right or wrong, I believe it is fair to claim that it should be right. It is difficult to undertake to prove that mathematics should be right. We are here dealing with a question of ethics, not with one of science. We do not expect an artist to be right or wrong; we could hardly accuse a metaphysician of being either right or wrong. The criteria of excellence of

performance in all such cases must be based on tastes—the tastes of the performers and their critics, and, according to the old maxim, *de gustibus non est disputandum,* albeit I know of nothing about which there is so much dispute as tastes, and for obvious reasons, which may account for the necessity of the maxim. The reason that mathematics should be right is because it can be; and for this reason, to avoid disputes, it has become the professional ethics of those who apply mathematics to get that part of their work right. So wide-spread is this ethics that in practice one rarely tries to check the purely mathematical work of an investigator. It is not that the principle of corroboration which pertains to all scientific investigation is in abeyance, but merely that the mathematician is expected to check, *i.e.,* to corroborate his own work so that the reader may take it on faith. Let us borrow the terminology of our societologists and say that it is in the folk-ways and mores of mathematicians that their mathematics should be right. Let us treat it as an axiom.

Why, then, should I make so much of the matter? Precisely because there are so many persons now using mathematics for the first generation in their respective sciences that it is advisable to set out what is the professional ethics of applied mathematicians. And because I regret to say that I have come across work by well-known investigators, in famous institutions, financed by generous foundations, work printed in journals of international repute, but unhappily so far from right that its wrongness can be recognized at a glance by any one really familiar with mathematical procedure. Evidently the work could not have been checked by the authors as it should have been or really read by an intelligent editor. This kind of writing and editing is a real imposition on the reader and necessitates some emphasis upon the duty of him who uses mathematics to get it right. Of course, we must not be too severe; accidents will happen and in any particular case it comes down to a matter of judgment as to whether negligence has been criminal.

Mathematics, assumed now to be right, may be appropriate or inappropriate to the problem in hand. This appropriateness is again very largely a matter of taste. One great advantage to the investigator of being familiar with a considerable variety of techniques and of the mathematical background of those techniques is that he has a greater experience and a sounder knowledge as a basis for his judgment as to appropriateness and is therefore likely to have better taste in such matters. I made mention of the method of least squares. I wonder if many of you realize how pervasively that method penetrates our statistical procedures even when it does not appear on the surface. Suppose we add a column of figures and find the mean. Do we stop to think that the mean is the least squares solution of the problem of finding one item to represent the whole group? The mean is nearest to all the elements of the group only if we take as the criterion of nearness the squares of the eccentric departure and not the departure itself. It is the median which we should use if our notion of nearness is to be founded on the departure instead of on its square, and I may recall to your mind that the great economist and statistician, F. Y. Edgworth, had a considerable partiality for medians—I know not why, perhaps merely as a matter of personal taste. Fortunately for many if not most problems, conclusions based on working with medians or with means are for practical purposes identical, but when they differ one may well hesitate.

To discuss a little this question of appropriateness of mathematics, let us take the purely hypothetical question: Where

should our association meet? How might a scientific member from among us solve this problem? As to this I have no idea; the ways of scientists are often inscrutable. One type of mind would doubtless construct a spot map of our membership scattered as it is about the country. If very conscientious, he would recall that many who are not our members but belong in associations which use statistics should perhaps be given some consideration, and he might therefore add to his spot map with somewhat reduced weight points to represent them. But how then select our meeting place? Should he determine the center of gravity of all the centers of gravity of all these points? Some would do so automatically. They would be, in fact, maintaining that the best point to meet would be that which minimizes the sum of the squares of the railroad fares that would be paid by all persons if all attended. And others might reason that what we needed was the point of greatest concentration of our population on the ground that it would be of maximum convenience to the greatest number—a just procedure provided not many would come from a distance anyhow. This would be selecting the mode. Still others might feel that all interests were best met by that point which would make the sum of the railroad fares least, being in that median sense the point nearest to the whole membership and thus presumably most convenient on the whole. It is clear that the scientific solution could be obtained only after determining that type of mathematical formulation which was most appropriate to the problem, and this determination would be a matter of taste.

Fortunately, we all know that we may be spared such a scientific determination of the place where we shall meet. Like as not, nobody would be satisfied with the solution anyway and at all events there would be years of dispute over the appropriateness of any methodology. Much more practical means suffice. The Economic Association determines willy-nilly to come to Washington; the Political Scientists feel an irresistible urge to celebrate their twenty-fifth anniversary at New Orleans, and the rest of us decide where we will go only after much discussion and perchance with small rational basis. This is one of those cases where pretty much all mathematics is inappropriate, where any mathematics whatsoever will give an entirely false sense of precision to a problem in which no precision inheres. And there are many problems in economics or sociology or the public health which are as yet very much in the same position and where we need not so much some kind of mathematics or some particular statistical technique as a general survey of a wide range of facts, many of them qualitative, which may serve as a basis for some decision.

Probably the majority of problems to which the statistician must turn his attention are in reality somewhat intermediate between those in which the technique to be applied is clear and those in which no technique, at least of a mathematical sort, is advisable. In this methodological no-man's land, the statistician must do the best he can. He may have to develop a new technique; in that case he has two chief reliances, first and foremost a sound and wide acquaintance with the field of activity in which he has to operate, and second a good mathematical background, because it is from that that all techniques are developed; but if choice must be made between familiarity with his subject and familiarity with mathematics, I should unhesitatingly prefer the former. Mathematics is a queer horse and all too easily runs away with its rider; and then there is such a satisfaction in trying its various gaits in all sorts of roads that many a rider has gone off in almost the opposite direction from the path he should have followed

in his pursuit of the solution to some scientific problem; he may have ridden right over his solution to some purely fantastic goal.

Each person has to do the best he can to bring to bear upon his work the talents and the training that he has. If I may be pardoned a personal confession, I will say that I have never been sorry that in my youth I acquired an unusually good acquaintance with mathematics. At times when engaged upon some statistical problem in physics, I have needed to learn new mathematics, but for the most part my early training has sufficed not only to let me follow the mathematics of others but, so to speak, to see through it with an assurance which sometimes convinced me that it was hollow. And if in my present studies I use but little of the vast amount I have once learned, it is not because I do not like the exercise of using it but because I prefer tools more appropriate to my job even though not so refined—one gets ahead faster.

Mathematics may be right or wrong, it may be appropriate or inappropriate, it may be useful or useless. There is many a useless problem. Sometimes one can not see it is useless until much time has been spent upon it. But consider this: I have a field in New Hampshire much covered with stones, rocks and boulders. With sufficient energy I could weigh all those objects, divide the weights into suitable intervals, plot a histogram and fit a frequency function. That would be scientific observation, followed by mathematical treatment of the observations. The problem is obviously statistical. It would keep me occupied for some time. But what would be the use? Of course if I knew enough about geology to be confident that my field was a fair sample of a large group of fields and if there was any geological or agricultural or constructional or other interest to be served in determining a frequency function of the weight of superficial stones from small to large from a "sample" field the job might not be useless but useful. But there seems at present no good purpose to be served by its doing. And often I wonder in some of my reading whether the hard work the author has done, though correct and appropriate in its mathematics, may not be quite useless.

What we need to foster is useful, appropriate, correct mathematics applied to worth-while scientific problems, and worth-while scientific problems whether or not they have reached the stage where any considerable use of mathematics is helpful. And in these vital matters, we have far more need of good taste and a sure instinct than is commonly believed, for it is so often only in the future that we can get a statistical estimate of the worth-whileness of present activities. Happy is the statistical investigator who can use all his techniques with discretion, and happy the teacher who can give his students some sense of proportion as well as a group of methods in such a conglomerate field as statistics.

Placed as I was upon the program between sociology and economics, represented by such giants as Presidents Ogburn and Gay, interested the one in making himself a mental centrifuge to precipitate the facts of recent social change from that murky colloidal solution we call the present, the other bent on crystallizing out from the subcooled liquor of our past the solid course of prices, it was quite impossible for me to determine whether I was to be the meat of your sandwich or the comic relief of your tragedy. Without pausing now to suggest an answer to this question, but rather in the continuing line of my previous remarks, may I direct your attention to that interesting statistical treatise "The Bridge of San Luis Rey," by Thornton Wilder. Some of you recall the story. The bridge fell, killing five

persons, and the devout Brother Juniper was struck by the question: Why did this happen to those five? And determined to surprise the reason of their taking off. It seemed to him that it was high time for theology to take its place among the exact sciences and he had long intended putting it there. What he had lacked was an opportunity for observation under *proper control.* Previous happenings had been involved, but here was a sheer Act of God and at last His intentions could be studied in a pure state. It was not, however, Brother Juniper's first essay in scientifically examining the ways of God to man. There had been a deadly pestilence of smallpox in his village and he had recently drawn up a diagram of the characteristics of fifteen victims and fifteen survivors, the statistics of their value *sub specie aeternitatis.* Each soul was rated upon a basis of ten as regards its goodness, its piety and its usefulness to its family group. As follows:

	Goodness	Piety	Usefulness
Alfonso G.	4	4	10
Niña	2	5	10
Manuel B.	10	10	0
Alfonso V.	–8	–10	10
Vera N.	0	10	10

The investigation developed difficulties; almost every soul in this little community turned out to be economically indispensable, and the column headed "Usefulness" was all but useless; negative signs had to be introduced to distinguish from the good and bad those who were not only bad (Grade 0) in and of themselves but actively led others into wickedness. From all this data the good scientific friar contrived an index for each person. He added up the total for the victims and compared it with the total for survivors—to discover that the dead were five times more worth saving. And then, taking a walk by the Pacific he tore up his findings and cast them into the ocean—a most profitable mode of publication and in a medium of the widest circulation.

So when he came to study his one great chance, the collapse of the bridge with its five victims, having experienced the bitter disappointments of statistical procedure, Brother Juniper forsook the method of W. F. Ogburn for that of W. I. Thomas—the case study. In compiling his book on these five victims he omitted no slightest detail for fear he might lose some guiding hint. He put everything down in the hope that the countless facts would suddenly start to move, to assemble and to betray their secret. Of one, the Marquesa de Montemayor, he learned from her cook that she had lived almost entirely on rice, fish and a little fruit, and he put it down on the chance that it would some day reveal a spiritual trait to aid in sifting the inscrutable ways of God. From another, he learned that she came unbidden to his receptions to steal the spoons. A bookseller testified that she was one of the three most cultivated persons in town. The midwife declared that she had called upon her with morbid questions until she became a nuisance; a servant that though absent-minded she was a compact of goodness. And so with many another in her respect and in that of the other four. We may pass over the conclusions to state that the book being finished was pronounced heretical and our scientific theologist Brother Juniper was burned alive with it—apparently to the great regret of everybody, but the simple persons of his time may not have had our overburdening experience with questionnairing.

With an apology to you and to Mr. Wilder for these few free quotations from "The Bridge of San Luis Rey" couched in a crude English that does him no justice, I will leave you with the suggestion that you study further this remarkable statistical romance, and I will

venture the hope that should the author make a few dollars extra from royalties because of this hint of mine, he should apply them to securing a membership in our association. Some of us need him in our business.

THE FOLK-WAYS OF A SCIENTIFIC SOCIOLOGY

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For long it has been a practice of sociologists to study the habits and manners of peoples. Therefore, it should be permissible to examine the habits and manners of sociologists, if the subject were sufficiently significant. It becomes significant, perhaps, and certainly intriguing, when one thinks not of the habits of present-day sociology but rather of the practices of a sociology of the future, when it has become more truly scientific than is the case to-day. Naturally we can not make precise predictions, but certain inferences can be drawn; and, then, it should be remembered that one of the customs of long standing among us is that a president of a scientific society in his presidential address is not expected to be bound so rigidly by the restrictions of data, nor is his imagination to be so disciplined as would be the case if he were presenting the results of a piece of scientific research. I shall draw rather more largely than usual on this freedom which I understand is allowed me.

One of the processes that will shape the sociology of the future is that of differentiation, described at such length by Herbert Spencer. It is, I know, not the fashion to quote Spencer these days. But irrespective of our intellectual styles, division of labor and differentiation continue to be powerful processes despite frequent exceptions. Historically the growth of the sciences has occurred by a processs of differentiation. Indeed, it is customary to note that philosophy was the mother of the sciences and that sociology and psychology are the latest to be separated from her, if, indeed, the separation may be said to have been completed.

No doubt this differentiation of subject-matter will continue, yet the reverse process has undoubtedly been operative, particularly in the United States, during the past decade. The reason is that this differentiating process has reached a stage where a particular science is quite inadequate to deal in any realistic manner with many practical problems, any one of which falls in the several different fields of the various social sciences, so that the dividing lines between the social sciences have been breaking down under the impact of certain researches particularly in the practical world of social life and the many problems which it presents.

But it is another differentiating process which will be of special significance for the future of sociology, a differentiation not so much of subject-matter as of methods. In short, the more strictly scientific methods will be differentiated from methods that more properly belong to activities other than those of science. I refer to such activities as are found, for instance, in ethics, religion, commerce, education, journalism, literature and propaganda. Sociology as a science is not interested in making the world a better place in which to live, in encouraging beliefs, in spreading information, in dispensing news, in setting forth im-

pressions of life, in leading the multitudes or in guiding the ship of state. Science is interested directly in one thing only, to wit, discovering new knowledge. As a human being, I, of course, want to seek for knowledge that will be of benefit to mankind. Similarly as a human being, I may want to spread this new knowledge far and wide, or to affect the beliefs of people or to write my interpretations of life and events. These activities may be just as important, or more so, perhaps, than discovering new knowledge. Indeed, it is hard to rank them in values, since they are all invaluable. But in so far as I function in these respects, however worthy they may be, I am not engaged in scientific activities.

The differentiating process will split off these various non-scientific procedures that are now so intertwined in the so-called scientific pursuits of the social scientists. When this is done, the sociologists will have abandoned some of their existing habits and will have developed some new ones instead.

One of these new habits will be the writing of wholly colorless articles, and the abandonment of the present habit of trying to make the results of science into literature, the precedents set in this regard by Huxley and William James being considered a bad legacy for the apprentices of science. It will not be necessary, then, to end articles with an eloquent appeal or a scintillating conclusion. It will be possible also to begin articles without referring to Plato, Aristotle or any other of the much-praised Greeks. Clarity and accuracy will be the only virtues of exposition. The expression of emotion will be bad form. The audience for these articles will be the scientific guild, and no attempt will be made to make these articles readable for shop girls or for the high-school youth. Articles will always be accompanied by the supporting data. Hence the text will be shorter and the tables and records longer. It will cost more to print them. Only part of the article will be read; the remainder will be for reference.

This specialization in the exposition of science does not mean that there will be any diminution in the popularization of science. There will be numerous articles and books which will show the human significance of these discoveries and measurements—publications which will dramatize science, which will rewrite scientific results in terms of slang, which will put in them an ethical punch. The scientist himself may engage in such types of writing, but if so it will be in the capacity of another self, not as the functioning of his scientific self.

And so there will be a new type of social science journal, not now in existence, save perhaps in one instance, which will devote itself to the publication of scientific results for a scientific audience. The articles in the new social science journals will be in some ways greatly expanded social science abstracts, that is, an abstract in the sense that the scientific essentials will be abstracted from the irrelevant interpretation, popularization and emotionalism. And so readers will go to the sociological journals in the future for one thing only, to find new knowledge. They will not expect, as they do now, a gratification of their esthetic sense, ethical edification or entertainment or stimuli for the projection of their personality.

In the future era of scientific sociology there will be a marked decline in the prestige of intellectuality as such, as compared with its vogue in the nineteenth and twentieth centuries. But this decline in the prestige of intellectuality will be only among the scientists themselves, for the difference between scientific activities and intellectual activities will be more sharply drawn. All scientists are intellectual, of course, but

only a very few intellectuals are scientists. The difference is very well noted in the comparison of two addresses by Renan and by Pasteur, at the time of Pasteur's reception into the Académie Française. Renan's was a great intellect, which shone in full brilliance in his address of welcome, an address of wit and charm, of lights and shades, abounding in intellectual subtleties, scholarly references and touching at times the profound. Pasteur, the scientist, in his address of acceptance, was not at home in the display of intellect as such. His was a simple, straightforward and by comparison dull presentation. This does not mean, of course, that scientists may not be great intellects. Quite the contrary. Intellectual play or display may be the recreation of the future social scientist, but hardly his main work. The disciplining of the mental processes is too strict in scientific work to permit intellectualism to flourish in the laboratory. Intellectual processes—as contrasted with scientific thought—are combined usually with feelings, though of course always in logical form. Impressions are followed more freely in intellectual life, wherever associations lead. But in the scientific work of proof, of establishing real enduring knowledge, thinking must be freed from the bias of emotion. There must be eliminated all the associations that disturb the closeness of the connection between the thinking and the data.

Of course the disciplining of thought is not so apparent in one of the steps in scientific work, *viz.*, the originating of ideas, or in the slang equivalent, "the getting of hunches." There imagination and free association are the greatest aid to the scientist. It is for this reason that one says, and quite truly, but rather crudely, that there is something of the artist in every great scientist. So intellectualism is the proper atmosphere for the birth of ideas. Getting the idea is often said to be the first step in the scientific process, but more often it does not lead to the new step—it only leads to the production of literature. But it must be remembered that getting an idea is not establishing real knowledge. An idea of value to science must be formulated in some sort of form capable of demonstration or proof; then must follow the proof or verification. An unrestricted propagation of ideas will not produce science. The shaman or medicine-man of the American Indians was not a scientist and did not produce scientific medicine, although he was very fertile in the production of ideas. The originating of ideas is a necessary step in the scientific work, but ideas must be formulated and tested by reality.

With the decline in intellectualism it will be less easy to get fame as a theorist, and with the rise of science reputations will be built upon proofs, records and measurement. But at times, fortunately gone by, in some of our social disciplines, a man had rather have been called a theorist than a scientist, a most peculiar twist in values, for in the natural sciences it is rather a matter of shame to be labeled as only having set forth a theory. The publication of guesses, hypotheses or hunches in this future era will be tabu. There will be no virtue in a merely stimulating article. The *sine qua non* of scientific publication will be verification and evidence. Verification in this future state of scientific sociology will amount almost to a fetish. There will inevitably be a great many unimportant and uninteresting things verified. Thus science will utilize the dull and uninteresting person, just as logic utilizes the paranoiac, as social philosophy utilizes the fanatic and as intellectualism utilizes the day-dreamer. For science will rest on a base of a great deal of long, careful, painstaking work. And many stupid persons can be careful, patient, methodical.

It must always be remembered that science grows by accretion, by the accumulation of little bits and pieces of new knowledge. Occasionally one of these little pieces of new knowledge becomes of very great significance and it is then called a great discovery or a great invention. But one can not predict when these very significant pieces of new knowledge will be discovered. The accumulative nature of the growth of science is usually not appreciated because of the prevailing opinion, influenced in part by the Comtean postulates, that the stage of proof and verification in the development of science must be preceded by a long period of theory. Such a sequence is true enough in the case of the verification of a particular hypothesis but not necessarily so of the development of a science. The growth of science is rather the accumulation bit by bit of new and lasting knowledge. The accumulation of these new discoveries calls for an organization of workers, not all of whom will be stupid, however, for brains are useful in science as in every other form of enterprise, and there will be geniuses in science as truly as in scholarship.

In this future state every one will be a statistician, that is, nearly every one. All the universities will have statistical laboratories and the individual workers will have plenty of machines, all of them electric. Indeed, there are likely to be more machines than thinkers. For some time, perhaps a very long time, however, a goodly portion of research in sociology will make no use of statistics. It is obvious, however, that quantitative sociology is bound to have an enormous growth, not only because of its undoubtedly great usefulness but also because we have the wealth to collect the statistics and the organization to provide for their analyses. While all sociologists will be statisticians, statistics as a recognized field of knowledge will disappear, and there will be no professors of statistics. Statistics will disappear as a distinct field of knowledge because it will be almost universal, not only in sociology and in economics, but perhaps in social psychology and in political science also. All the journals in the different social sciences will publish statistical articles. With the growth of statistical research, it will become more and more apparent that statistical method as such can not well be divorced from the data. Hence, statistics will be identified with the subject-matter in each social science rather than be set apart as a special discipline. Indeed, this tendency is making great headway in the United States at the present time—much more so than in Europe.

In the past the great names in sociology have been social theorists and social philosophers. But this will not be the case in the future. For social theory and social philosophy will decline, that is, in the field of scientific sociology. Social theory will have no place in a scientific sociology, for it is not built upon sufficient data. Of course, certain syntheses of broad researches may be called theory, a new meaning for an old term. But such syntheses will be based on evidence. Social theory in good part is a product of wishful thinking, taking form in the *Zeitgeist* in which it is developed. But so were the superstitions of the primitive cultures, such as, for instance, the theories as to the origins of the world and how it was peopled. Many of the great social theories will collapse, just as the theory of supernatural beings once collapsed, for it is possible for a great body of intellectual ideas of a people to have no abiding truth in them. A scientific sociology will be quite sharply separated from social philosophy, for it will be recognized how much social philosophy is a rationalization of wishes. Social philosophers will continue to exist, however, and serve a

very useful purpose in such fields as ethics and among publicists and statesmen.

One of the qualities most sought after by scientific sociologists will be patience, which will be accorded rank as one of the major virtues. Fame, publicity and emotional gratification will appear always as temptresses, but the scientist will be loyal to patience. Although the dynamic qualities of human nature are furnishing him with the drive to make his goal, nevertheless, without caution and suspended judgment, they will prevent him from attaining that goal. Brilliance and originality will always be admired, but in a scientific sociology they will never be admired alone, that is, without the accompanying proof and measurement that comes with perseverance and patience.

This insistence upon "suspended judgment" is not compatible with action, which tends to follow directly out of emotion. The caution of the scientific mind in reaching a decision is illustrated by the conversation of the scientist and his traveling companion as they looked out of the train window at a herd of sheep. To the remark that the sheep had been sheared, the scientist replied, "They seem to be on this side." Such extreme caution and insistence on "suspended judgment" is not compatible with executive ability. It is, though, a desirable quality in judicial ability, although judicial decision is more often hasty than is scientific conclusion.

The scientific sociologists will not, therefore, be statesmen, leaders or executives. And if they ever seem to guide the course of evolution—which neither they nor any one else ever can do—it will be indirectly, by furnishing the information necessary for such supreme direction to some sterling executive who will appear to do the actual guiding. In some rare cases a person may be both a scientist and an artist. But, if so, the guiding of the ship of state will be done by only one of his two personalities, the executive one. This differentiation of the scientist from the administrator has already gone far in this country, farther than in Europe, and it is noticeable in our universities.

While the sociologist as scientist will not hold office or lead movements, this does not mean that he will be an armchair sociologist or that he will necessarily live a secluded life. On the contrary, the scientific sociologist must become more and more realistic and he must learn to know his data by the closest of connections with the sources wherever they may be, in social movements or amidst social problems. He will be found with the staff of the courts, in the factory, at the headquarters of the political party, in the community centers. He will be wherever data on significant social problems are to be found. But he will be there as a student to discover new knowledge and relationships rather than as a practical worker. The executive, the leader, the social worker will be the group to put to use the information which the scientific sociologist furnishes. For, as some wag has said, "Making butter is different from spreading it."

In the future the subject-matter of the social worker and of the sociologist will be the same, in large part, except that the field of the sociologist will be larger and will encompass that of the social worker. The interests of the social worker and of the sociologist will also have more in common, for a large group of sociologists will deal with the practical problem of human betterment. And to a certain extent the motivation of the social worker and of the sociologist as a human being will tend to be the same, for the social scientist, being human, will be interested in making the world a better place to live in—at least, most of them will. But they will go about it in

different ways. The sociologist will of course work on the problems that tend to make sociology an organized systematic body of knowledge, but also he will choose for his researches the study of those problems the solution of which will benefit the human race and its culture, particularly those problems that present the greatest acuteness. But the scientific sociologist will attack these problems once chosen with the sole idea of discovering new knowledge. Whereas the social worker will be interested in applying the new knowledge thus discovered for the alleviation of the ills of mankind, either as a social engineer or as a leader of a movement or the executive of institutions. But with the rising standard of living which will come with a lowered birth-rate, with the many new inventions that are inevitable and with our wonderful natural resources, the nature of the problems of the social worker will tend not to be set off as a class dealing with poverty but rather with social problems in general. The social worker and some of the sociologists will thus work together at the same place, the one interested in discovery and the other interested in practical achievement. The two functions may indeed find existence in the same person.

Both the sociologist and the social engineer will require much more scientific discipline than do the natural scientist and the mechanical engineer. One reason is the greater temptation to distort conclusions in the interest of emotional values. Furthermore, the social engineer will not be able to restrict himself to the application of proved knowledge, for social problems will be so urgent that one can not wait on the "suspended judgment" of the scientist. Something will have to be done. We must vote on the first Tuesday after the first Monday in November, whether our information is complete or not. Social problems call for action as well as knowledge. Now, knowledge is usually a matter of probability. Hence action will often be based upon approximate knowledge, when, for instance, the probability appears greater than 50–50. Fair success in using approximate knowledge in important issues will of course bring social approval. This means that high standards of science will always be hard to maintain in the social sciences. Also, unless social values change greatly from what they are to-day, the leader and the executive will command greater prestige than the scientist who discovers new knowledge for the leader and executive to use. There will always thus be a great mongering with proximate information. But there will also be social engineers who, like physicians in general, are not scientists, but who apply reliable scientific procedures and relatively exact knowledge. But the scientist's work will be differentiated from that of the handling of proximate information and the applying of exact information already known according to formula.

A great deal of research will be done outside of universities, an increasingly large proportion. A smaller and smaller proportion of research will be done single-handed by the lone researcher. This is regretted by some schizophrenic persons who believe that one can not think if one works in an organization. The fact that a clerk's life is a routine and that the punching of adding machines is mechanical is not evidence that nowhere in the organization are there persons who think. All governments, national, state and city, may be expected to increase their research functions greatly. But so also will trade unions, employers associations, leagues and civic bodies, political parties, industries and social work organizations. Increasing wealth will make such social research possible, and secondly, its effectiveness

will be increasingly demonstrated. All these various organizations with special interests will be doing research with a specific purpose to prove a particular hypothesis or to gain a desired end, but their research staff will be dictated to only in the choice of the problem or hypothesis. They will be free to abide wholly by the evidence. To do this they must be sharply distinguished from the executive or policy-making branch.

This differentiating process which will mark off science in sociology leaves us without a wholly attractive or ideal picture of science and scientists. But a forecaster is not interested in whether what he sees is beautiful or not. His idea is to predict solely what will happen. But of course I realize that according to the folk-ways of America in the first part of the twentieth century, all addresses, like the moving pictures, theaters and short stories, are supposed to have happy endings—particularly presidential addresses.

The happy ending for a scientific sociology will be its achievement. It will be necessary to crush out emotion and to discipline the mind so strongly that the fanciful pleasures of intellectuality will have to be eschewed in the verification process; it will be desirable to tabu our ethics and values (except in choosing problems), and it will be inevitable that we shall have to spend most of our time doing hard, dull, tedious and routine tasks. Still the results will be pure gold and worth the trouble. While science will separate itself from education, propaganda, ethics, journalism, literature, religion and from executive leadership, of course all these excellent social activities will not cease. Social life will be thus just as rich. And, finally, it is not necessary for a scientist to be a scientist all the time. He can temporarily shut the door to his laboratory and open for a while his door to the beauty of the stars, to the romance of life, to the service of his fellow man, to the leadership of the cause, to the applause of his audience or to adventure in the great out-of-doors. But when he returns to his laboratory he will leave these behind, although there is a beauty, a romance, a service, a leadership and an adventure of a kind to be found sometimes in the laboratory.

LIGHT THROWN BY GENETICS ON EVOLUTION AND DEVELOPMENT

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At the beginning of this century two epoch-making events occurred in biology. One was the publication of de Vries' "Mutationstheorie." This book gave the results of years of experimental breeding with several species of plants, but especially the evening primrose. It opened up a lot of questions that plainly could be answered by the experimental method. It clearly revealed that variation could and must be made the object of experimental inquiry.

The other event was the rediscovery of Mendelism. Mendel's paper of 1865 was brought to light practically simultaneously through the independent work of de Vries, Correns and Tschermak. Their work, confirming Mendel's, proved that heredity could be profitably studied experimentally.

Now mutation and heredity are clearly factors of evolution. The experimental study of mutation and heredity inspired by these writings was begun twenty-five years ago on a large scale by many persons; and we might have hoped, and many of us did hope, that we should come to understand better the factors of evolution; that we should, indeed, be applying the experimental method to the problem of evolution itself.

Not all biologists were friendly to that view. Bateson, especially, insisted that heredity should be studied merely as a branch of physiology; and I am sure that he felt that the name, "Station for Experimental Evolution," which had been applied to a department of the Carnegie Institution of Washington was ill chosen. Bateson alas! is gone now, but the question he proposed is still with us: "Is the experimental study of mutation and heredity capable of throwing light on evolution?" Twenty-five years of endeavor have given experience bearing on the answer, and it is to this question that we will in a minute turn.

At the beginning of the century there was still a third biological subject that had been investigated longer than the other two. It was not commonly, if anywhere, regarded as having any relation to the other two that I have mentioned. This is the study of development of the individual. There is no science that has a more interesting history. It began with the investigation over one hundred and fifty years ago, by Kaspar Friedrich Wolff, of the development of the chick inside of the egg-shell. He was led to make cross sections of the early stages and to note the marvelous foldings of membranes that constitute such an important part of the process by which organs are formed. Then came von Baer, whose studies were so extensive as to lay the foundations for embryology as a new science. The key-note of this science was, for him, *Beobachtung und Reflexion*. For Francis Balfour it became *Beobachtung, Vergleichung und Reflexion*. The last third of the last century will be known in biological history as the period of enormous development of this science. With the aid of new methods of sectioning and staining and with the opportunities afforded by marine laboratories the developmental stages of all classes of animals were being investigated. The first aim of that period was to gather light on interrela-

tionships of organisms; to reconstruct the phylogenetic tree. Ontogeny, it was held, is an epitome of phylogeny.

Later, development became studied as a physiological process; the determination of the spindle-axes in cell-division, the interdependence of parts in development and finally the phenomena of differentiation in development were studied, and the latter, as the subject-matter of causal, or experimental, embryology, is being actively pursued to-day. But in all these phases of study of embryology its contrast to the study of evolution was plain. In general, ontogeny and phylogeny remained very distinct and apparently unrelated disciplines.

At this time I propose to consider the light that experimental work on mutation and heredity has thrown on the process of evolution and to show that embryology is now closely associated with the other two subjects and throws its light on the nature of evolutionary processes.

First of all, it becomes necessary to redefine "heredity." The definition of resemblance between parent and child is quite inadequate and unbiological. I think we may more appropriately speak of heredity as the science of the internal factors that direct development. This definition ties up heredity and development very intimately.

That there are such internal factors is obvious to any student of the development of the egg into the adult. I may place two just fertilized eggs, one of a starfish and one of a sea-urchin, in a finger-bowl of sea water, and they will begin their development in a uniform environment—uniform at least to the outside observer. In the course of a few hours, or days, one of them will develop into a young starfish and the other into a young sea-urchin. The external conditions are the same. The internal driving influences are responsible for the difference. This fact does not oppose the other fact that if I were to place two fertilized eggs of the starfish, one in ordinary sea water and the other in sea water in which the proportion of salts had been doubled, the resulting young starfishes would be very different in form, if indeed both survived. In studies in heredity a uniform optimum set of environmental conditions is assumed. The fact that changing environment may induce changes in the course of development is not denied or overlooked. It is for the purposes of the problem of internal directive factors for the moment disregarded, since environment is made as fit as possible for the developing embryo.

The mechanism of inheritance has long been a subject of speculation. Since egg and sperm are equal carriers of heredity, yet have little in common but their nuclei, the nucleus was early regarded as the carrier of the mechanism of heredity. Weismann worked out in detail its rôle, and on speculative grounds concluded that the germ-plasm or the totality of the chromosomes was the special mechanism. The work of the past quarter of a century, under the influence of Morgan, has placed this hypothesis on a firm basis of fact. Now we know the essential thread in the course of evolution; it is the germ-plasm; and the problem of evolution is the problem of the history of the germ-plasm. Some one has said that the hen is the egg's method of making more eggs. One may even more truly say that the hen and the cock, the man and the woman, are the germ-plasm's method of perpetuating itself; of multiplying infinitely its particular kinds of genes.

We exist as we are because our germ-plasm has determined us, and we fail of our *raison d'être* if, that germ-plasm being evolutionarily fit, it fails to be carried on. Perhaps, one may argue, the failure to be carried on indicates unfit-

ness for evolution. More properly it may signify an unfitness of our woefully distorted civilization to permit of the continuance even of the otherwise excellent germ-plasm.

But if mankind has too little regard for its duty of perpetuating its own best germ-plasm it has no doubt at all of the value of the best germ-plasm of the thoroughbred horse or the dairy cow. Hundreds of thousands of dollars will be paid for a stallion whose racing days are over, but whose personal and family history prove the peculiar value of its genes. By weight the best germ-plasm is the most precious of all purchasable materials. On the other hand, it may be the most precious of free gifts. Little wonder it is so valuable; it has cost an infinitude of lives to make it what it is.

But the continuance of the germ-plasm, though necessary to evolution, will not suffice to produce any evolution. Evolution implies change. Let us see what the experimental work of the past quarter of a century has brought to light in regard to changes in the germ-plasm—which we call mutation. It is in this field that the greatest discoveries have been achieved. This is the great contribution that the twentieth century has already made to our knowledge of evolution.

The quarter century of experimentation has shown us the way to separate inheritable variations, or mutations which have an evolutionary significance, from paravariations which are primarily somatic in their nature. But the clear distinction between these two types of variation has with further study become vague, inasmuch as even paravariations are usually produced under the influence and control of the internal factors, operating always in relation to environment. The effect of environmental factors depends not merely upon their nature, but above all upon the nature of the genes also.

The experimental study of mutation has shown us, first of all, that the chromosomal mechanism, so carefully protected, so carefully evolved and so well fitted for its purpose of continuing the organic world, is subject, by its very complexity, to accidents.

First of all, we are struck by the marvelous behavior of chromosomes among themselves. As is well known, the somatic chromosomes of an individual, A, are ordinarily in pairs, one of each pair having come into A with the egg and the other with the sperm. At the time of formation of the gametes—at meiosis—these pairs of chromosomes come together and lie alongside of each other, like ends together. If the chromosomes of the pair differ by only a few genes they may still undergo this synapsis which precedes gametic formation. But if the corresponding chromosomes are very unlike, as is the case when the egg and the sperm that united to form the zygote A are very different (of different species M and N), the corresponding chromosomes may not undergo synapsis when the germ-cells are formed. The germ-cells may contain a heterogeneous collection of chromosomes unreduced in number in which certain essential chromosomes are missing, while others are double in number. Such zygotes die. The species cross is sterile.

But if, by chance, any germ-cells receive a complete set of the chromosomes of both M and N and two such germ-cells come together, then the hybrid will have each chromosomal element of both species (M and N) doubly represented and the hybrid will propagate itself indefinitely with the double set of chromosomes, as Karpetschenko and others have shown. Thus will have originated, by hybridization, a new form which breeds true, has several or many new

differential characters and is practically sterile with other forms. It has all the characteristics of a new species; it is a new species.

That in nature new species have sometimes arisen in this fashion is indicated by the marvelous fact of polyploid series which have been worked out in some plants. Thus there are found in nature allied species whose chromosome numbers are multiples of a basal number. For example, in wheats we get chromosomal numbers 7, 14, 28, 42, being multiples of 7. In the genus Rosa are found 14, 21, 28, 35, 42 and 54, all but the last being multiples of 7. In Rumex is one series 8, 16, 24, 32, 48, 64, 80; another series, 12, 24, and still another series 20, 40, 60, 80, 100 and 200 chromosomes. In Datura 12, 24, 36 chromosomes and other multiples of 12 have been found in the course of experimentation. Polyploidy has clearly played a part in species formation.

Again, chromosomes undergo other changes which induce great variability and even variety-formation. The variability of the evening primrose, which attracted de Vries' attention, is now recognized as due to varied chromosomal arrangements. In Datura the phenomenon of cross unions between non-homologous chromosomes discovered by Belling has been further investigated by Blakeslee. Some of such unions may well give rise to constant new species.

As to the cause of these chromosomal mutations some things have been learned. Thus different types of radiations will induce them. It is probable that cold, by reducing the protoplasmic sensitivity, is an important agent. Now polyploid species grow more vigorously than those with fewer chromosomes; cold induces polyploidy and since it is useful for the plant to be able to grow as rapidly as possible in a region with short summers, polyploidy may sometimes be a highly self-adaptive mutation to meet the conditions of a cold climate.

In the second great class of mutations, not the chromosome as a whole but its constituent genes (or units of inheritance) may be changed.

This is the type of mutation that has been most thoroughly worked out in insects, but it seems to be universal. It gives rise to Mendelian inheritance. In this type single genes in the chromosomes are altered and correspondingly single somatic characters or single groups of them are changed. Such changes, once arisen, go down through the generations. In the domesticated plants and animals the numerous races are usually due to this so-called point mutation. But also wild species, as for example the native violets, seem often to depend on this sort of mutation.

The number and kinds of point mutations that can occur in a species is determined by the total number of genes, and this is limited. Consequently the repertoire of variation in any species is limited. Accordingly we find parallel variation in the species of a systematic group. Thus, among mammals, we have albinos in very many domestic and feral species. Hairlessness repeatedly occurs but is best known, naturally, in domestic animals, like horses, cows, guinea-pigs, mice, dogs. Polydactylism is found in dogs, cats, guinea-pigs, mice and rats. Long hair, rough coat, short head, taillessness, varied eye color, are found in many species.

Now an important outcome of experimental genetics is this. Not only do point mutations occur in connection with the maturation of the gametes, but also during the development of the soma. Such a mutation is commonly more or less sporadic in occurrence. One sees it, for example, in a dwarf Portulacca which sends out a branch that is of full size. One sees this somatic mutation in

a red-stemmed plant of which one branch is green. That the germ-plasm has mutated in these branches is clear from the fact that the germ-cells that mature in the full-sized branch of the dwarf, or the mutated green branch, carry genes for full size or green stem, respectively, unlike the gametes of the unmutated branches. Thus the somatic mutations may establish different (but usually not wholly novel) genetic lines.

Somatic mutation is in some cases not sporadic, but its occurrence is regular and controlled. Such mutations are found in variegated plants. Thus one sometimes finds an ear of yellow corn where the kernels over a considerable area are red. The affected area has undergone a somatic mutation from yellow to red.

The process of somatic mutation is well illustrated in the larkspur, Delphinium (as shown by Demerec̆), where the light pink petals are regularly variegated by darker spots—areas of denser anthocyan pigment. In some strains these spots are small; in such, somatic mutations occur late in the development of the petal. In other strains the spots are larger; the mutation occurs early in petal development and affects a larger area. The point is that a hereditary, racial character is due to an orderly somatic mutation. This case is of inestimable importance. It is proof that differentiation in this case, at least, is due to somatic mutation. But the case is by no means unique, and many patterns in plants are doubtless due to such somatic mutation.

It is alluring to speculate upon this discovery and to formulate the hypothesis that the spotted pattern of mammals, *e.g.*, of the coach dog, and of birds, and the stripes of reptiles and mammals are due to such somatic mutations. Perhaps some day the entire process of differentiation may be found to be due to a regularly recurring series of somatic mutations.

However this may be, in some species, as *e.g.*, Delphinium, the course of embryological development is, in part at least, controlled by precisely the same mutative changes as the course of phylogenetic or evolutionary development. Thus we see that the course of evolutionary development and the course of individual development may be due to the same causes. Where embryological development and evolution are so intimately related we can better understand the significance of the adage referred to above: "Ontogeny recapitulates phylogeny."

What is the cause of this mutation, so fateful for evolution? The late Danish geneticist, Johannsen, based his theory of the pure line upon the idea that sexual mixings are necessary to the production of genotypic differences. According to this theory a homozygotic line that is reproduced without sexual reproduction, like the potato, or by self-fertilization, like the bean, undergoes no mutation. This view is, we now know, chiefly through the remarkable experiments of Banta, too narrow. Banta has carried certain parthenogenetic lines of Cladocera (water-fleas) through 850 generations, reproducing only parthenogenetically. During this time great numbers of mutations have occurred, both of a morphological and of a physiological sort. Thus he has gained many strains quite distinct from that one from which all started. One of the most important results of all those years of experimenting in genetics is the demonstration that the germ-plasm is constantly mutating. These facts are so clear as to lead us to rephrase the old problem of evolution and instead of stating it as the problem of the origin of species think of it as the problem of why any species remains long constant. Perhaps the assumed con-

stancy of species is due to the fact that we have known them for so short a time and that we have really followed the "blood lines" of very few wild species of plants and animals. Certainly the mammalian paleontologist will not find the view of constant rapid mutation unacceptable.

What are the causes of point mutations? How are they brought about? In many cases, as in Banta's Cladocerans and many lines of Drosophila, we seem forced to conclude that mutations may occur spontaneously, that is, from internal causes like the breaking down of the uranium, radium, lead series. From this point of view the cause of evolution is to be found in the nature or constitution of the genes themselves.

However, the changes of the germplasm may be hastened, we have learned in the past few years, by the direct action upon them of X-rays and radium. This discovery of Mavor, Gager, and especially Muller, provides a routine process in inducing gametic mutation now used in many genetical laboratories. And Patterson has recently shown that somatic mutation may be similarly induced.

Not only radiations but also changes of temperature cause a change in the rate of gene mutation in Drosophila, as Muller announced before the American Association for the Advancement of Science three years ago. "Gene mutation," he said, "can be affected by temperature, even as chemical reactions are affected, and the results can be measured."

Recently we have seen an attempt made by Babcock and others to test the hypothesis that it is the radiations of the earth that are inducing mutations in the genes. Drosophilas reared in a tunnel, deep in the mountains where radiation was strong, produced more mutations than in the laboratory, where radiations were feeble. These results seem to be confirmed by the recent experiments of Hanson. They throw light on the rate of production of mutations; they confirm what we know from other experiments, namely, that radiations may accelerate the mutative processes.

Since external conditions, such as temperature and radiations, can control the rate of mutation, the hypothesis would seem tenable that all mutations are so caused. It does not appear, however, that increased temperature calls forth or produces mutations that would otherwise never have occurred, but merely accelerates the realization of potencies wrapped up in the genes. Any chemical reaction is, within limits, accelerated by raising the temperature. The increased temperature is, however, not the cause of the specific reaction, but rather the cause lies in the nature of the interacting reagents.

Also, it seems probable that radiations are not the primary cause of gene mutations but that they accelerate processes that are initiated by the internal structure of the genes.

That the essential nature of gene mutation is determined primarily by internal conditions is well shown by the experiments of Demereč. Thus in Drosophila there is a sex-linked gene that is chiefly responsible for reddish body color. This reddish mutates back to the wild type; but it does so only in females and such females as are heterozygous and it mutates only at the time of maturation divisions. In another mutant of Drosophila (miniature wings) Demereč has found a gene that mutates both in males and females and at all stages of development, so that somatic mosaics are produced. Such behavior of the mutating genes is certainly incompatible with the hypothesis that cosmic influences are necessary to set off the gene mutation. The gene has internal capacity for mutation just as an alarm clock has an internal mechanism for

ringing a bell at a particular time. Gene mutation can arise from the very mechanism of the gene.

Mutation is, however, not the only evolutionary process. Were it the only process, the organic world would now be in a state of chaotic disorder. Hardly two individuals would be even approximately alike and vast numbers would show all gradations from the effective to the most helpless cripples and half-developed monstrosities. In such an organic world the idea of applying to organisms the concept of species would hardly have occurred to a Ray, or of listing and naming species by an improved system to a Linnaeus.

Actually we find in nature a limited number of categories that we call species. Actually the individuals composing these species are not only effective but they are things that are interesting or beautiful in form and color. For the most part these species are more or less sharply marked off from each other.

What is the additional factor which is responsible for this orderly organic world of species?

This factor is one which has brought about a wide-spread adaptation of organisms to their environment, and the mechanism that has brought about this adaptation is the environment itself. To survive, a mutation must meet the conditions imposed by a very puritanical environment. And, indeed, environment is not only puritanical; it is also hard-boiled. If the reward for those who meet the conditions of environment is bliss the penalty of those who fail is death.

Into the rigor of environmental selection the last few years of genetical research have given us a new insight. First of all, it is quite clear that only a part of the gametes are capable of forming zygotes. To commit a Hibernianism we may say vast numbers of individuals perish before they are conceived. Of the zygotes started many are incapable of passing through more than a brief development. Thus in mice half or more of the eggs that are ovulated fail to develop into young mice, and of the young mice born only a fraction mature. Of the potential seeds in the pod or capsule only a part develop, and of the developed seeds only a part germinate when planted under good conditions. In humans the children that are born are a residuum merely of the zygotes that started, and early infancy is the great period of further elimination of the non-viable. Those who live to be parents are a highly selected segregate of the population of zygotes that began development, the grandparents are a still more highly selected segregate. Many are the zygotes that are called into existence, but few are chosen to carry on the race. We esteem the patriarch not because he is old but because environment has so often given him the O. K. Honor thy mother and thy father. Emulate them in being in tune with environment so that like them you may live long in the land.

Genetics is causing a *volte face* in our view of the effect of social work. The physician and the sociologist have been inclined as they look at the world of human unlikeness in body, mind and disease-resistance to find a firm point of departure on a tacitly assumed homogeneous early stage. Differences in behavior of children are ascribed to differences of experience in infancy; and, if you insist that infants are already unlike at birth, then varied intrauterine experiences must be responsible. On this hypothesis the population of early zygotes is uniform; dissimilar environments cause variation. If environment is made uniform then all the longed-for machine-made-uniformity of each product will be achieved. For on this basal assumption the sociologist feels he can rest, and from it he can start: all fertil-

ized eggs of the species are exactly alike.

Genetical experience points just the other way. The foundations of the sociologist are rotten. The population of fertilized eggs is the most diverse of all populations. Life is a process of elimination of the extreme variants—before birth, in infancy, in childhood and youth. The end result—the mature man and woman—is the least variable population of all—certainly in its genetic aspects. Out of great heterogeneity of zygotes has come an approximation to homogeneity in the adults. Environment, acting as censor, tends to keep the species homogeneous and pure.

To recapitulate, the study of genetics has thrown light on evolution first of all by its intensive study of mutations—which has resulted in locating mutation in changes in the chromosomes—the germ-plasm. The study of genetics reveals the germ-plasm as undergoing changes in its composition at particular points and finds that these changes may be hastened among other agencies by radiant energy. But the radiant energy is not the sufficient or a necessary agent. Not sufficient, for only such mutations occur as the nature of the genes permits. Not necessary, since mutations occur that certainly seem to be independent of any environmental change.

The study of point mutation has revealed the fact that it occurs not merely in the process of forming germ-cells but also during the course of somatic development, thus determining differentiation. Indeed, somatic mutation may occur in so regular and orderly a fashion as to be responsible for a developmental pattern. Mutation may hold the key to developmental differentiation.

If gene mutation falls short of explaining all the elements most commonly found in species-formation, all such elements are provided in chromosome behavior. For new chromosomes introduced into the chromosome-complex may set up housekeeping with the old, will bring in many differential characters at one time and will breed true. The new combination will show low fertility with the old or with other new combinations. The characteristic traits of species differentiation all follow the formation of new chromosomal aggregates.

Finally, mutations, though limited in their variety by the nature of the mutating genes, still dart out in the most varied and often little-adapted directions, like the movements of the "it" in "blindman's buff." But progress is made in the direction of adaptation when environment's signals become effective. Genetics alone is incompetent to give a complete picture of the processes of organic evolution. Genetics and ecology, working together, are competent to explain evolution.

THE BISON AS A FACTOR IN ANCIENT AMERICAN CULTURE HISTORY

By Dr. WALTER HOUGH

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ZOOTECHNY, a term introduced by O. T. Mason to cover the correlation of man with animals, is more comprehensive than the animal industries of G. Brown Goode's classification. The subject is ramifying and has important bearing on man's progress in culture.

It is obvious that in preagricultural times tribes favorably situated as to meat supply enjoyed advantages over other men. Notably, also, grades of culture conformed to the character of the food supply, even those grades having access to animal products being low compared with races depending on the yield of cultivated plants. It is seen that of the groups entering America those connecting with herds of herbivorous mammals, the only animals capable of furnishing an abundant and reliable supply of meat, skins and other useful products, would have a great advantage.

In the high north the reindeer answered the condition in part, the remainder being supplied by fish and aquatic mammals. The migratory habit of the reindeer was a drawback to the tribes of the north whose dependence upon aquatic life required fixed habitations along the shores. For this reason the actively shifting reindeer could not be kept in contact by tribal movements, and a state of dependence on a major mammal was not realized. Incidentally this more comprehensive subsistence induced a more varied or even higher culture than in tribes which became commensals to migrating mammals. The shore-living peoples considered above are typified by the Eskimo.

Migrants from Asia, following the reindeer and reaching the interior, assumed other phases of subsistence midway between that of the Eskimo and that of tribes pushing further south, namely, a rationing of fish and the meat of mammals. We may consider this phase to obtain up to the Slave Lake region where contact with the buffalo could begin.

What would appear to have been the most important event in the life of Asiatic tribes assimilating themselves to American environments was getting in touch with the buffalo. We can say that aside from food and materials needed in the majority of arts, the buffalo was instrumental in diffusing the Asiatic widely and rapidly in America.

Under no other conditions of "infiltration" would these aliens arrive relatively soon at the frontiers of an environment capable of molding civilization that would eventually react strongly on other populated environments in the spread of its culture.

That the buffalo was the important factor in first sustaining the tribes drawn into its range is maintained here. If this theory is accepted it may be advanced, first, that tribes of an early period hunting buffalo would be introduced into the wide stretches of plains otherwise uninhabitable as providing none of the prime requisites of life. Even with the buffalo as sustenance the Plains would be a repressive environment unlikely to produce or maintain anything but a low stage of hunting culture. Second, in this buffalo complex we would have tribes of low culture closely associated with this animal and gradually extending to the extreme limits of the range, say the approximate present

Mexican line. So far as is known now this condition existed for a long time. No tribes of the character suggested appear to have survived to the period of the repopulation of the Plains by northern Indians, which occurred with increased rapidity in the historical times after the introduction of the horse.

Third, we may suppose that in the movements of former tribes with the buffalo some units became peripheral and located in environments capable of human sustenance. It may be inferred that in some instances tribal segregations of this kind would initiate steps leading to higher culture. Of them can be cited the preagricultural Basket Makers, occupying a desert environment, whose arts indicate the genius which became the remarkable Pueblo culture. The period of the agricultural Basket Makers was about 2000 B. C., according to Kidder, whose estimate is based on the early type of maize in possession of these people.

Modern Pueblo research indicates that the people in the grade of the preagricultural Basket Makers had spread widely in America. Already by the efforts of Kidder and by others under his inspiration, the bounds of this rude substratum have been greatly enlarged. The indications are that the range of the Basket Makers will prove astonishingly great.

The presence of Pueblo remains on the Canadian in the Amarillo region, west Texas, furnishes a glimpse of possibilities of the transition of Plains culture into a peripheral culture that penetrated the Pueblo region of the southwest as the initial Basket Maker phase. This theory seems plausible, but its substantiation depends upon an intensive exploration of some of the typical Canadian River pueblos. Some good work has been accomplished by Dr. W. C. Holden, but in a limited degree. Superficially the pueblos seen by the writer under the guidance of Mr. Floyd Studer in the breaks of the Canadian twenty miles north of Amarillo, Texas, resemble those of Pueblo I sites worked by Dr. Frank H. H. Roberts in 1928 in western Colorado. Especially suggestive are the round and rounded rectangular plans defined by stone slabs set on edge. So far no coursed masonry has been seen on the Amarillo sites. Trial excavations by Mr. Studer in house débris deposits show layers defined by charred basketry, small stakes, ashes and mussel shells. Flints, arrow-heads, scrapers and chips are abundant. There is a little pottery of a rude character. Dr. Holden secured a pottery vessel of coarse paste with combed or scratched surface. This vessel is globular with constriction above giving a scarcely defined neck. The vessel has a wide opening. In some respects it is like specimens secured by Dr. Roberts from Chaco Canyon, New Mexico. On the flat land and slopes down into the breaks are innumerable plans in stones, round like tent sites, large circles and rectangular stone-bounded areas. Quantities of variegated flint derived from a neighboring quarry cover large areas and chips dot the surface.

The surrounding scenery reminds one of the Pueblo region with buttes, bare slopes, and sage, yucca, cactus and other desert plant species.

Work is needed here urgently to decide whether this is a Pueblo beginning or, as was thought by former investigators, a backwash from the Pueblos. It is clear in any case that we have here a mingling of Pueblo and Plains culture and a most interesting problem of American archeology awaiting solution.

A more important example is the archaic horizon of Spinden and Gamio in Mexico. The archaic peoples of Mexico made pottery and cultivated maize and, therefore, do not represent the earliest rude tribes of the region who no doubt utilized as a means of subsistence

the agave culture plant primarily and the other useful plants and animals of the diverse regional environment of Mexico.

Before the peopling of Mexico and the relatively rapid growth of arts there it is inferred from cultural remains to the north that the tribes generally were on a low plane belonging to tribal subsistence by hunting. Gradually maize was introduced among them, originating in Mexico perhaps around 3500 B. C., and passed from tribe to tribe over a long period. With reference to the antiquity of maize it may be said that the earliest Maya date, 622 B. C., found that people with cultivated corn. Beyond this to the primary cultivation of maize is conjecture, and a tentative date based on Kidder's estimate of 2000 B. C. for the Basket Makers would be 3500 B. C.

With the tribes in immemorial contact with the buffalo a state of divisional subsistence occupation was superimposed, changing the hunting tribes in less degree than those planted in favorable locations as noted.

The latter responded to a greater degree to the stimulating effect of maize, in fact, the native cultures were profoundly enhanced by this cereal. It may be affirmed that the higher cultures of America began with maize. Also, as the writer has stated in another place, the diffusion of maize was not uniform and at the beginning of the historic period the plant was not yet in the possession of all the tribes, especially those isolated by mountain barriers and having an adequate environmental subsistence of their own.

Returning to the roving buffalo-hunting tribes it may be said that the time here covers a long period characterized by little cultural change. The time is probably long enough to include the ultimate disappearance of all species of bison except the form prevalent in the historic period. In this view it appears that some of the older species now called fossil were on the point of disappearance at the coming of man to America. The cause may have been the crowding out of the older bison by the more prolific modern species. The Folsom find suggests a *battue* in which the dwindling remnants of an ancient herd were slain by ancient hunters perhaps with the throwing stick type of hurling weapons.

The researches of paleontologists have shown that a number of species of bison inhabited America after Pleistocene times. Necessarily the ranges of the older species are not known, as all information is yet fragmentary, but it is likely that the species distribution became local in its later phase and much more restricted than that of the historic buffalo. This idea is based on the grassing of sedimentary deposits following the last glacial epoch remaining in place long enough to produce a soil cover suitable for the growth of grass species. The correlation of buffalo species with grass species also is suggested as a well-known phenomenon of natural life relating to such dependencies.

There is suggested here the probability of cropping ranges at different geological periods on the Plains and low interior lands. So far as is known, the development of the ancient species of buffalo took place on the same character of terrain as that forming the range of the historic bison and would be coincident with the extensive grassing of alluvial deposits. It is probable that the conditions were best for the vast increase of the latter species, but an authoritative statement can not be made.

It is most likely that the contacts of Asiatics in America were with species of buffalo antedating the present form continuing with the current species. The conditions in general appear to have forced the old species of bison, coming over the land bridge from Asia, southward to extinction and late survivals in

favorable areas, as appears to be shown in Dr. Gidley's exploration in Florida. Other conditions led to the growth of the present almost extinct species into the form described by Cabeza de Vaca in the fifteenth century and seen in such prodigious numbers by the first travelers to the interior of America.

Some years ago it was not perceived that the contact of Asiatic settlers in America would have been with the extinct species of bison. But recent discoveries put a new light on their early contacts in America.

Leaving the theoretical prelude, suggestions and possibilities aside for what they are worth, some tangible facts may be taken up. Several years ago at Folsom, New Mexico, artifacts consisting of chipped stone points were found with the remains of a number of specimens of an extinct buffalo. Owing to the many unproved, doubtful and scientifically unchaperoned "finds" that had been announced disappointingly through a long term of years, this discovery was viewed with proper caution.

In this case, however, the find was in the hands of scientific men and the work was carried on in a thorough manner. There is no room for doubt that the stone points of some weapon were observed in position among the skeletons of the extinct buffalo. This fact is indisputable. Beyond this the conclusions that have been advanced as to the age, the position in the geological scale of the deposits in which the artifacts were found and their particular type are as yet tentative. Dr. Adolf Penck, the weight of whose authority on valley cutting and fluvial terrace deposits is internationally known, would put the age at not more than 9500 years, and this figure he regarded as tentative.

The Folsom discovery is placed to the credit of Harold J. Cook and J. A. F. Figgins. Dr. Barnum Brown, of the American Museum of Natural History, conducted the subsequent work for that institution. Since the connection of man with the buffalo at Folsom is based on chipped stone projectile points of a certain class, some remarks on their manufacture and type may be introduced here.

The form, which is a thin blade spoon-shape at the forward end and worked out into an arc at the base, is wide-spread in America and is distributed over the world sparingly as to the National Museum collections of Old World archeology.

The flint worker chipped the blade into shape normally and the unfinished implement had a straight base. The base was then worked into the arc of a circle by flaking from either side alternately, as in making the nocks on an arrow-head. In order to thin the bowed median axis of the implement a broad flake was taken out on both sides, producing a reasonably flat surface for hafting. Almost all stone arrow-heads worked in from the base show flakes taken off vertically. Flint flakes, or blanks, can not be struck off with biconcave surfaces, although one surface shows a concavity. By the method described the flat side of the flake can be hollowed.

It is suggested, therefore, that the biconcave Folsom blades were made of this type on account of the thin hafting desired, as the like blades of Ohio, Georgia and other localities in the United States. It would seem that there is little racially, tribally or geographically characteristic connected with the Folsom blades.

At Frederick, Oklahoma, a similar discovery of the association of man with an extinct species of buffalo was made by Mr. A. H. Holloman, owner of the sand pit, and examined by C. H. Gould, state geologist. Owing to conditions which made the find less clear than that

of Folsom, the discovery was at first discredited, but subsequently regarded as authentic, though not very ancient, especially as it is in line with the former work and not one of the many tantalizing isolated finds.

It would seem that the discoveries of traces of man in beds assigned to Pleistocene have put scientific men on the horns of a dilemma. The crux is that man is very ancient in America or the beds recent, that the animals found carry man back very far or that the cultural objects declare for recency of man. Impartially viewing the evidence, it seems that the beds are recent relatively and that archeology is more concerned than geology in the findings.

Thus the archeologist applying the culture development schedule of his science would believe that the finding of arrow-heads, pottery and grinding stones in undisturbed fossil beds as at Frederick, Oklahoma, would indicate that the beds date from a comparatively late period of human arts.

In fact, the material so far taken out with the remains of bison and mammoth would fit in best at the Neolithic period. The Neolithic besides is a master period in which there was world-wide distribution of man over the earth. American tribes as they came into the light of history were Neolithic in arts and physically typical Indians.

Nevertheless latitude must be given to the supposition that the end term of migrations before the European Neolithic, progressing slowly on the long march toward that phase of art, may have reached America. Also it is not supposable that all increments arriving at different times in America possessed the same grade of Neolithic culture or the same physical characteristics.

The unity of the Indian race inhabiting the New World at the beginning of European contacts is now taken for granted. This view follows many years of discussion of various traits dealing with dissimilarities and resemblances which were supposed to yield classificatory data leading to the naming of many races within the stock. With the advent of physical anthropology was established the fact that from one pole to the other the Indian varied only slightly within the limits of a physical unit type.

The first implication from this unity is the ruling that the wide distribution geographically of a uniform type is proof of comparative novelty of its diffusion. It is also assumed that considering the historic Indian the initial migrants coming into America over Bering Strait were of that stock whose increase populated the western hemisphere. While this is the observed result shown in the Indian, the original uniformity is conjectural. There is a possibility that diverse stocks may have come in at different times and have finally merged into the known Indian or passed out without trace as yet.

Countering this is the fact that all skeletal remains so far found under conditions denoting presumed antiquity are shown by Dr. Hrdlička to conform to the Indian physical type. This is in obvious contrast to results in Europe and may be considered safe ground for the conclusion that man in America has no ancient or geological history of moment.

THE CULTURE OF THE BAYA TRIBE OF WEST AFRICA

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THE Baya tribe is located in French Equatorial Africa in the upper Congo basin southwest of Lake Tchad. This tribe is composed of about 200,000 natives. According to Froebenius and Ankermann, they belong to the West African culture area, which comprises all the Bantu peoples of the Congo River basin and its tributaries. Bantu tribes living in close proximity to the Baya are the Karre, the Mandjia, the Kaba, the Dapa and the Banda. Each of these various tribes has a population ranging from 50,000 to 200,000.

I. Climate, Geography, etc.

This section of the country covers an area of about 150 square miles. As a whole the country is rolling, although in places there are mountains. The elevation averages about 1,600 feet above sea-level. There are some large rivers, especially the Ouham and Sanga, but they are not navigable for very long distances because of the many rapids. The soil is very rich owing to its virginity. Tall grass, some of it twelve feet high, covers the whole area. Dwarf trees are abundant. Every year the natives burn the grass and this stunts the trees. Along the streams there are dense forests and undergrowth. There are two seasons: the rainy season, which occurs from April to November, and the dry season corresponding to our winter. Both seasons are hot. The sun is dangerous because of the direct or actinic rays, although the thermometer does not register much above 90 degrees in the shade. It is necessary for all northern Europeans and Americans to wear helmets of cork or pith.

There are many swamps, and consequently malaria is ever present, especially with the white people. Along the streams and other low-lying country is found the tsetse fly, the great scourge of Africa. This fly causes sleeping sickness, for which science has not yet found an altogether satisfactory remedy. At times whole herds of animals die because of becoming infected with this disease.

II. Manner of Living

Formerly all villages were located on hilltops and were protected by hedges of cactus. Recently the French government has compelled all villagers to move to more accessible regions. The natives live almost exclusively in villages. Isolated dwellings are rare. The country is sparsely populated and between villages there are miles of uninhabited regions. The village stands as a unit. Each individual thinks of himself as related to the others. Often there is war between the villages because of the stealing of wives or property.

Houses are cone shaped and usually about nine feet in diameter. The walls are made of woven mats, or at times of clay. The roof is made of thatch and the floor of clay beaten very hard. There are no windows and only a small opening for the door. The inside is partitioned off into two or three parts; one part to sleep in, a second in which to store pots, etc., and a third for the fireplace.

The granaries usually consist of large baskets about four or five feet in diameter and elevated on wooden posts to keep out insects and small animals which are ever present. Chicken houses are also elevated in the same way to keep out wild animals.

The men's clothing consists of loin-

A GROUP PICTURE

NATIVE GIRL GRINDING FLOUR

NATIVES MAKING A MAT

cloths woven on crude little weaving machines, which are made by driving several sticks in the ground. They raise cotton from which they spin their thread. Thread is spun with a very crude spindle made by taking a stick and weighting it at the lower end with a wheel made from a piece of baked or burned clay. Sometimes they wear loin-cloths of bark which has been peeled from certain selected trees. They soak this bark for several days and then it is beaten until it becomes thin and soft.

The women usually wear large bunches of leaves, but there are some who also wear a small apron made of cotton threads. Near the trading posts they are beginning to buy cheap calico whenever they can afford it. The native is very proud of any clothes he can obtain even at the expense of making himself look ridiculous. Once a man was seen going down the road walking very proudly because he was lucky enough to possess a fan and a dilapidated umbrella.

The men usually cut their hair short but at times they braid it. The women also generally bob their hair, but at times they braid it in many tiny small braids close to the head. In times of bereavement the head is shaved.

Beads are worn in profusion, the brighter and the more colors the better. The women wear them around their waists, around their necks and on their arms. Bracelets, anklets and crude rings are worn. The nostrils are pierced and on both sides long ornaments are suspended. A hole is pierced in the lower lip and an ornament placed through it.

Tatooing is done extensively throughout the tribe but seemingly without signification.

III. Occupation

Agriculture is carried on extensively by the women. The two staple foods are cassava or manioc and kaffir corn, which are beaten into flour and mixed in hot water until it becomes like dough. After it is baked it takes the place of our bread. Yams, millet, pumpkins, beans and cucumbers are grown extensively. Small patches here and there are cultivated by hoes with short handles. They do not use fertilizer but clear off a new garden spot whenever the old one wears out.

Both spinning and weaving are done

by men. From cotton they spin the thread for their loin-cloths. They also weave baskets and mats.

Mats are woven from strips cut from palm-leaves and certain kinds of grass. They are used for beds and floor mats. Some of them are beautifully made, having designs of different colored strips.

The natives make many different kinds of baskets. They employ the same methods as they do in making mats, although in some places coiled baskets are made of reeds. They also make hats and bags which necessitate slightly different methods from those used in making mats.

Pottery is developed quite highly in this section of the country. The making of pots is always the work of the women. They make pots of all sizes ranging from those large enough to hold a pint to those that hold about ten gallons. Most of them are decorated with crude designs. The pots are made of a special clay and are burned in a charcoal fire after shaping.

Chickens are domesticated but are much smaller than in America. Goats are kept, not for milk, but for meat. They are also used as a medium of exchange in buying wives. They have some small dogs which are very skinny, as the natives take away any small animals which they catch. There are a few horses scattered throughout the country. There are no cattle because of the tsetse fly.

The Baya are great hunters. The grass is burned by the natives every year and many animals are speared as they try to escape. They throw their spears very accurately and rarely miss their animal. They also use the bow and arrow and at times poison their arrows, rendering them very deadly. The traps are made by having a noose on the end of a rope. A hole is dug in the trail of an animal and the noose placed around the circumference of the hole. It is concealed with sticks and leaves and the free end of the rope is tied to a sapling. The animal walks into it unaware. Sometimes they dig a deep hole in the ground, concealing it by placing sticks and leaves over the opening. The animal falls into it and can not get out. In this region one finds many different kinds of animals, such as elephants, hippopotamuses, crocodiles, lions, leopards, buffaloes and antelopes.

Fishing is an important occupation among many of these people, especially those who live along the large rivers. Sometimes the native climbs up in a tree and crawls out on a limb which reaches over the water and waits for the fish to swim by. When a fish comes within range he throws the spear at it. Oftentimes there is a hard battle to land these fish because of their extreme size.

Canoes are made by digging out the inside of a palm log or other logs. Paddles are used for rowing. In some places the natives stand up and row in unison, often chanting rhythmically as they row.

Metal working is a very important occupation. The natives mine their ore, smelt it and then pound it into tools or money. The blacksmiths are the gifted men of the country. There are only a few of them and they are looked up to and respected, for "No blacksmith, no spears; no spears, no war." Knives are at times decorated very beautifully and require some skill in making. The people pride themselves on their spears and take a great deal of time in their manufacture. They also make arrows, bracelets, hoes, axes, throwing knives, hole diggers, adzes and other small articles. Their money is sticks of iron about twelve inches long by one sixteenth of an inch thick by about a quarter of an inch wide.

A TYPICAL BAYA MAN

IV. Social Organization

The population of the villages ranges from fifty to two thousand people, but the average village has only about three hundred natives.

The country is ruled over by chiefs, each chief having a village under his control. The chief has the right to compel his people to work for him and supply him with food. If they refuse he either flogs them or has them jailed. Each subject helps to support the chief by bringing him a part of his produce when harvested. The chief receives his share of every animal killed. Each chief, however, is responsible to the French government and must see that all his villagers pay their taxes and do a certain amount of work for the government. The chieftainship is inherited by the eldest son on the paternal side.

Sometimes a village is composed of several sections, and as the chief can be at only one place at a time he sets captains over these different divisions. They rule as chiefs in their own division but are responsible to the head chief of the village.

The tataways are assistants to the chief who help in the enforcement of law. Usually they are the friends of the chief or the influential men of the village.

In Baya land whatever an old man says is respected and usually obeyed. It is the old men who cling to the old customs and traditions. They are the teachers of the young. Sometimes an old woman is looked up to as the "mother of the village."

Marriage is exogamous, the members of a village usually marrying outside their group. A man seeks a wife in a neighboring village. The marriage is arranged by the fathers or elder brothers of the young people. The girls are bargained for when they are not more than a year old. The bride is usually taken when she is seven or eight years old. The purchase of a wife is quite an undertaking and oftentimes expensive. A wife may cost as much as four hundred sticks of native iron money, two goats, four spears and two knives. If the man seems anxious for the girl, the mother-in-law may intervene and demand that the young suitor come and carry wood and water for her for a week, or perhaps the mother-in-law may want the mother of the groom to make her some salt. If the wife dies without having any children, her father must forfeit the bride price or give another daughter in her place.

Polygamy is common. A man's wealth depends upon the number of wives he possesses. Chiefs have been known to have as many as thirty-six

wives. Many men have two or three wives, but ordinarily they can afford only one wife. A man is loath to give up his many wives, for as he says, "It is all right when my wife is well, but should she get sick, what would I do for food and who would make my garden, if I only had one?" Each wife has a separate hut where she lives with her children. The wives are glad for their husband to have several wives because it lessens the amount of work each has to do.

Divorce is at the will of the husband or wife. If the wife leaves her husband he can demand the return of the bride price.

Private property in land is recognized; nevertheless, each village has a particular section of the country which belongs to it for hunting purposes. When a man dies the relatives inherit the property and his wife receives nothing. The son, if there is one, usually becomes the heir.

V. Religion

Everything and every place is animated with evil spirits. Gacora is the highest one of these spirits. He is the author of evil and is feared by all. They have no conception of a God of love as we have, but one of terror. When some one dies the relatives say it is because of an evil spirit in one of his enemies. The witch doctor determines who the guilty party is and then the relatives of the individual proceed to punish the victim. They may put red pepper in his eyes or force him to drink the poison cup. Flogging is also used as a means of punishment.

There are many sorcerers or witch doctors who are greatly feared by all. If some one is sick the witch doctor determines who the guilty party is. He places certain foods on the taboo list. He is supposed to heal the people of their diseases by manipulating his charms. If a married couple prove childless, they may take a chicken to the witch doctor who sacrifices it. As a result of this ceremony they are blessed and will be able to have children.

The natives believe in blood sacrifices and offer them for many different things. When a member of the family dies, the head of the family takes an offering to Gacora to appease him so that he will not take another member of the family. When an animal is killed, certain parts of it, such as the tenderloin and liver, are sacrificed to the god of hunting in order that the devotee may possess great skill in hunting. Every year they have a "feast of the dead," when they offer up many chickens and goats to the evil spirits so that they will not claim any more of their number by death.

Charms and fetishes are worn in profusion, each one having a different meaning. A string of small bones was removed from a baby's neck when it was brought to the dispensary for treatment. The mother said she had put these on to keep the baby from taking cold and pneumonia. A young man wore a particular kind of carved stick on his wrist while journeying through the jungle. Upon questioning, he said that it was to prevent the lions and leopards from killing him. Charms are also worn to give the wearer strength.

After death, they believe, the body decays. The soul separates from it and wanders around in the jungle seeking for an opportunity to cause trouble to some one. The soul becomes associated with the evil spirits. Their idea of the after life seems very vague and mystical.

VI. Art

Art is little developed, although there are some realistic designs crudely made on their houses or earthenware pots. Beautifully colored designs are woven in their mats. There is a small amount of ivory carving which has reached a high stage of perfection.

TERRESTRIAL MAGNETISM FROM THE VIEW-POINT OF THE ENGINEER

By N. H. HECK

CHIEF, DIVISION OF TERRESTRIAL MAGNETISM AND SEISMOLOGY, U. S. COAST AND GEODETIC SURVEY

There are going on at the present time several experiments in new forms of government. Whatever may be the outcome of these experiments, one of the strong elements of stability is the fact that the United States, after 150 years, is functioning without radical change. Originating in a world which regarded war as an essential part of national existence and having itself found it necessary to take part in a number of wars, it is now pressing strongly to eliminate war. These things are not the result of chance but are directly due to the fact that the discovery of America came just when it did. Political events of the succeeding period, more than at any other time in European history, developed in such a way that some of the strongest and best elements of the population left to try their fortunes in the new world. This was possible because of Columbus, and, back of him, because of one of the most important discoveries and inventions of history, namely, the discovery of terrestrial magnetism and the invention of the magnetic compass. While it is possible that these came from China, it was at this time that they first became known to Europe.

In recent years a new device, the gyrocompass, has come to the aid of the mariner and has in part replaced the magnetic compass, but the latter will still continue to be used and all mariners' charts carry magnetic information. However, if not another magnetic compass were to be used, the debt of mankind would still be great to the apparatus which first made it possible to cross the oceans.

The early colonists in this country had more land than they knew what to do with, but as time went on it became necessary to survey the land and mark the boundaries, as is evidenced by the fact that George Washington did some of this work. The magnetic needle in a form different from that used at sea but embodying the same principles made the work possible.

Engineers now have much more precise instruments, but we must remember that in those days not only were precise instruments and men who could use them not available, but even if they had been, the value of the land would not have warranted the expense. There are, therefore, thousands of land surveys made by magnetic methods in all parts of the country, and the Coast and Geodetic Survey is called upon daily for information from its store of records which will aid in repeating old surveys or searching for lost corners. Here again we see an important use of knowledge of the earth's magnetism.

In our time we have had other pioneer performances, not perhaps comparable with the voyages of Columbus but still highly significant, in the conquest of the air. Here again terrestrial magnetism has come into play, and the magnetic compass either of the globe type or the earth inductor type have become the best direction-indicating devices which are available everywhere and under all conditions. Lindbergh used a magnetic compass in his historic flight. All the airway maps carry magnetic information as a result of wide-spread demand from air navigators.

Useful accomplishment, a criterion which appeals especially to the engineer, has been shown. Other practical applications will be described, but it is first

necessary to enter a field which at first thought appears to belong exclusively to the mathematician and the physicist. However, engineers are becoming more and more interested in research and will have to become accustomed to entering such fields, or at least learn what is being done in them. I feel that it will be of interest to consider a problem in research which is of a different type from that usually engaged in by engineers.

In the applications that have been mentioned, it has not been necessary to consider the intricacies of terrestrial magnetism. An analogous case is the use of the relatively simple conception of elastic limits and breaking stresses in materials, while investigations indicate that these are only approximations.

There are few more complex subjects in the range of physics than terrestrial magnetism. Years ago it was thought that the great variety of tides in the different parts of the earth could not be reduced to law, but mathematical treatment has completely triumphed. This is not even remotely true in the case of terrestrial magnetism, and though every resource of the rapidly developing knowledge of physics has been utilized, we are still at the threshold of knowledge. We might be nearer solution if we had centuries of accurate observation instead of little more than a quarter century (considering the earth as a whole). By solution I mean not only full explanation of the phenomena but knowledge of the laws so that prediction may be possible.

The failure to respond to the world-wide attack on the problems is not due to lack of organization or hesitation to apply every possible new method. Something has been done in nearly every country and especially in Great Britain, France, Germany, Canada and the United States. In the United States, the magnetic surveys have been made by the Coast and Geodetic Survey, and the records of its five observatories have, in addition to the immediate purposes for which they were taken in connection with the activities that have been described, proved of fundamental importance in all studies of the nature of magnetism and its governing laws. The Department of Research in Terrestrial Magnetism of the Carnegie Institution of Washington (hereafter referred to as the Carnegie Institution and in some places abbreviated C. I. W.) was organized for the primary purpose of studying the earth's magnetism. It found insufficient information on hand for its purpose and has had a remarkable record of collection of information in all parts of the earth where it was not being done otherwise, and especially at sea through the work of the non-magnetic ship *Carnegie* and the brigantine *Galilee*. While thus a vast amount of magnetic data has been collected over the earth's surface—both land and sea—nevertheless, in view of the changes in terrestrial magnetism constantly going on, this organization like all others must continue to make repeat observations at suitably selected stations from time to time and must operate observatories at places not otherwise provided for. However, since the period of intensive collection as a major function in delineating the distribution of the earth's magnetism is now past and observations may now be generally restricted to the needs of secular variation determination, ever-increasing additions to the fine accomplishments in the field of research may be expected.

Coming back to the general statement of the problem, the first need is for accurate data over long periods. Accuracy in this case means all that the term can imply. The unit of measurement of magnetic intensity is the gamma, .00001 of the small c.g.s. unit, the gauss, and in some computations one hundredth of a gamma is used, so that we are dealing with quantities that are comparable respectively with one hundred-millionth and one ten-billionth part of gravity. While the accuracy of one gamma is not always attained, sustained effort is made

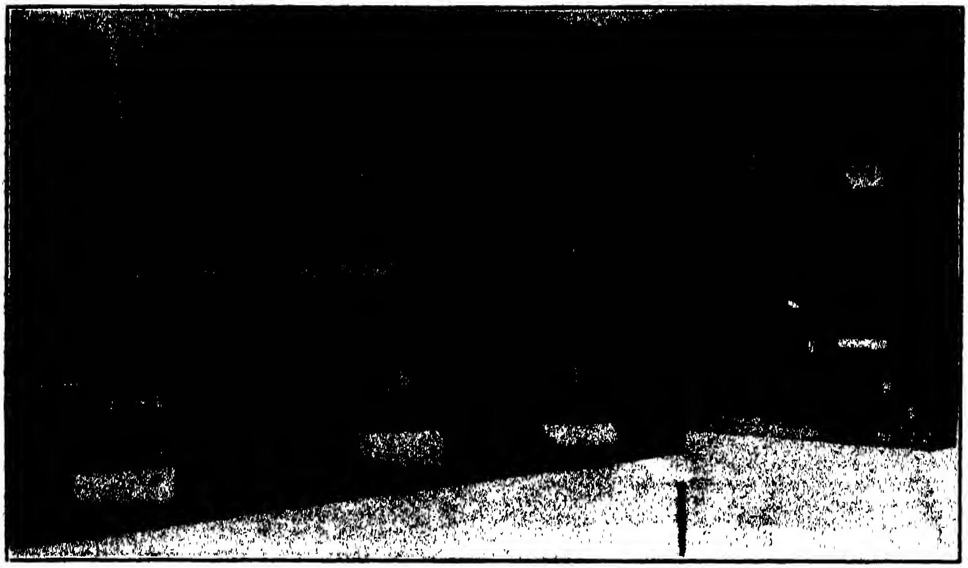

FIG. 1. MAGNETOGRAPH
CONSISTING OF THREE VARIOMETERS AND PHOTOGRAPHIC RECORDER.

to keep the uncertainty of the value as nearly as possible to one gamma. Observations of this order of accuracy are not infrequent in the physics laboratory, but in very few cases are they maintained over a quarter of a century. Time alone brings instrumental troubles, and bad weather conditions have their effect. In spite of these, three observatories of the Coast and Geodetic Survey have unbroken series of accurate observations for more than twenty-five years — those at Cheltenham, Maryland; Honolulu, Hawaii, and Sitka, Alaska.

The methods of observation are described in various publications, and there will be given here only sufficient outline so that the research problems in connection with them may be understood. One set of instruments records continuously by photographic methods the changes in the magnetic elements, declination, horizontal intensity and vertical intensity and, therefore, indirectly the dip and the total intensity. Other instruments are used to determine at regular intervals, as once a week, the absolute values of the declination, dip and horizontal intensity and, therefore, indirectly the vertical and total intensity. We then have absolute values for certain points on the continuous photographic records and, accordingly, it becomes possible to obtain the absolute value at any time desired.

The instruments for recording changes are known as variometers and a complete set with a recording unit as a magnetograph (Fig. 1). Though the variometers vary in appearance and details, they have the common feature that a magnet is suspended in such a manner that it will move from a position of rest only in response to changes in the particular force whose direction and intensity is to be measured. In the case of declination the magnet is free to take the direction of the horizontal component of the earth's field. In the case of horizontal intensity a small magnet suspended by a quartz fiber is held in the magnetic prime vertical by means of torsion in the fiber. A fixed magnet at a suitable distance controls the sensitivity and, as a recent development, another auxiliary magnet (Fig. 2), also fixed in position and having a suitable relation to the

suspended magnet, compensates for temperature. One of the important factors in securing results of the desired accuracy is the determination of the effect of the changes of temperature of the recording magnet and making corresponding correction of the results. By the method referred to, the auxiliary magnet and the suspended magnet are affected the same amount by a given temperature change but in opposite directions, so that the effect of temperature change is eliminated.

The prevention of slipping of the quartz fiber in its cementing medium was an engineering problem on a microscopic scale. While the forces are very small (fiber usually about 0.05 mm in diameter) the holding surface is so small that the forces causing slipping are relatively great. A solution has been found by heating the ends of the fiber and bending them at right angles to the fiber before imbedding them in the cementing medium.

The magnet system used for measurement of vertical intensity (Fig. 3) includes a magnet something of the shape of the walking-beam on a side-wheel steamer, the magnet being mounted on steel pivots which rest on agate planes. Since the magnet would tend to take a position with its axis in the direction of the earth's field, counter-weights are used to keep it horizontal. It might at first thought seem that there would be slipping and change of position of the pivots on the planes, but there is none because all the effective forces are vertical. In view of the perfect balance required, which is more accurate than that of the best analytical balances, it has been found necessary to fasten the counterweight rigidly in position and to use pivots of a special alloy. The load on the pivot points is on the order of twenty tons to the square inch.

Each magnet has a mirror attached and each variometer has a fixed mirror. The same beam of light goes to each pair of mirrors and then back to a clock-driven drum carrying photographic paper. We, therefore, have three pairs of lines, each variometer mirror producing an irregular line and each fixed mirror a straight line which serves as a base line from which to measure ordinates (Fig. 4).

The building which houses these instruments is built so as to keep temperature changes within small limits, and chemicals are used to reduce the humidity if necessary. In extreme cases, as in Porto Rico, a special casing is built around the variometers to make the air space from which the moisture must be removed as small as possible.

We are accustomed in many branches of science and in engineering to new and better instruments and methods, and it is an interesting contrast that the method suggested by Gauss about one hundred years ago is still standard for absolute observation of declination and intensity. Though with the development of standard coils and resistances electrical meth-

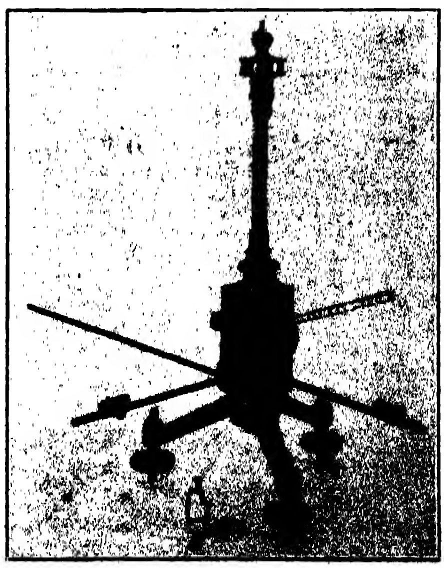

FIG. 2. HORIZONTAL INTENSITY VARIOMETER

EQUIPPED WITH APPARATUS FOR TEMPERATURE COMPENSATION.

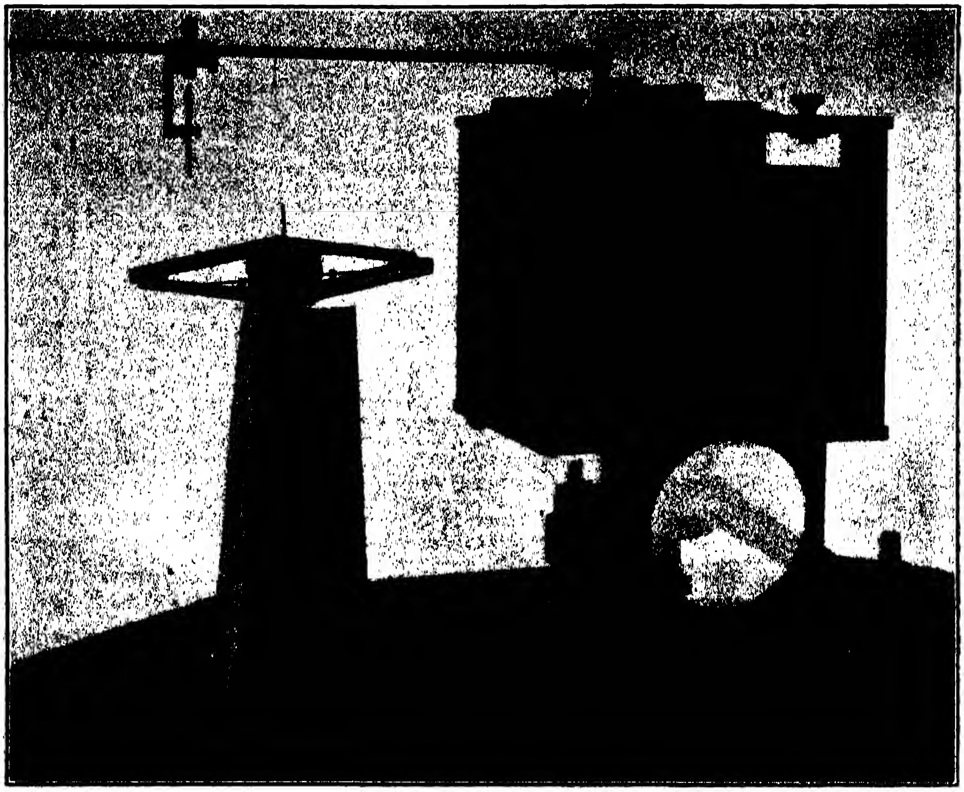

FIG. 3. VERTICAL INTENSITY VARIOMETER
SHOWING RECORDING MAGNET AND OPTICAL SYSTEM.

ods are now available, they have not yet replaced the Gauss method, though the latter has the disadvantage that the observations cover so long a period that the element being measured is likely to change during the measurement. The difficulty in the case of the other methods is that, since the gamma is so small, the electrical measurements must be of an accuracy which it is difficult to obtain at all times.

The absolute measurements of declination and horizontal intensity are made by means of the magnetometer (Fig. 5). Magnetic declination is obtained by determining the angle between the direction taken by the suspended magnet and the direction of a fixed object. The true bearing of this fixed object is determined by astronomical observation, and the difference of the two angles thus obtained is the magnetic declination. Determination of horizontal intensity is a double operation, one part being the precise measurement of the time of oscillation of a magnet suspended with its axis in the direction of the horizontal component of the earth's field and the other part the determination of the position taken by the suspended magnet due to the combined effect of the earth's field and that of a fixed magnet. The first gives the product HM and the latter the quotient H/M, and the two equations thus obtained can be solved for each. (H is the horizontal component of the earth's field and M is the magnetic moment of the suspended magnet.) Recently it has been found possible to measure the time of oscillation without using the eye-and-

ear method. A light beam is reflected (Fig. 6) from the polished end of the suspended magnet through a slit so that for an instant during the swing the beam strikes a photoelectric cell. This is recorded directly on a chronograph and the interval between successive swings can be accurately measured (Fig. 7). The problem was far more difficult than in the case of recording time of oscillation of a clock pendulum, since the oscillation in this case is limited two degrees and since it is necessary to have the apparatus far enough away from the magnetometer to remove magnetic effect at the suspended magnet and yet there must be enough intensity of light to operate the photoelectric cell.

For accurate measurement of the dip the earth inductor is used (Fig. 8). This is in effect a small dynamo coupled with a galvanometer. When the coil is revolved with its axis in the direction of the magnetic lines of force no current is produced, though in every other position there is current. With a very sensitive galvanometer, it is possible to make not only an accurate determination of the dip but also of the magnetic meridian and, therefore, of the declination. The last is the general principle on which the earth inductor compass works.

The transformation of the variation curves into hourly absolute values formerly required four distinct operations in the case of intensity. The ordinates were measured in millimeters, then multiplied by the scale value or number of gammas corresponding to a millimeter of ordinate. This gave the difference in gammas between the curve and the base line, and to this there was still to be applied the absolute intensity in gammas corresponding to the base line and the correction for temperature. The Coast and Geodetic Survey has developed methods whereby but one operation is necessary after certain preliminary settings of the apparatus have been made, and all this work is done at the observatories, except that the necessary settings are controlled from Washington and the results are reviewed there and put in form for publication. Temperature effects are eliminated by a method which has already been described. The conversion of

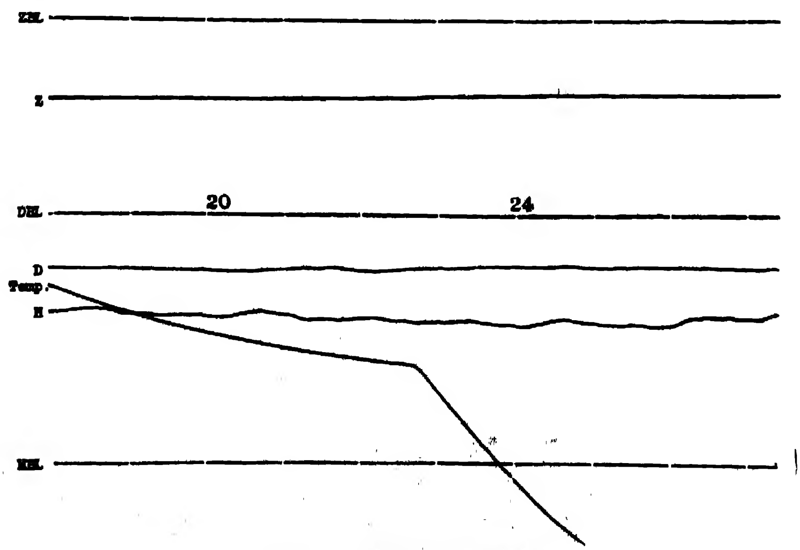

FIG. 4. MAGNETOGRAM

SHOWING TEST OF TEMPERATURE COMPENSATION. TUCSON MAGNETIC OBSERVATORY, NOVEMBER 18, 1929.

FIG. 5. MAGNETIC OBSERVATIONS
WITH OBSERVATORY MAGNETOMETER AT SITKA, ALASKA.

ordinates to gammas is accomplished by having linear scales for each scale value prepared by photographic means. By suitable arrangements the base line value is applied at the same time that the ordinate is read. At every step labor-saving devices are used to minimize the very great amount of detail necessary, and finally publication is by photographic reproduction of the sheets resulting from the final tabulation so that proof-reading is kept to a minimum and the cost of publication is considerably less than by printing.

The source of accurate information regarding the earth's magnetism and its changes comes from the records of forty to fifty magnetic observatories and also from observations of absolute values at points scattered throughout the earth. While the latter observations are not continuous, "repeat" observations are made at a certain number of them (as, for example, two hundred to three hundred in the United States) at intervals of five to ten years to determine secular change. With the loss of the non-magnetic ship *Carnegie,* whose tragic destruction last year brought to an end observations which had extended over a period of twenty years, the problem of securing repeat observations at sea has become a serious one, and it will at least become necessary to make more intensive repeat observations at land stations near the sea to make up in part for her loss. It is to be hoped that a means may be found for carrying on further observations at sea.

Though there are probably sufficient magnetic observatories to meet all needs if they were well distributed, this is not the case, as a very large proportion of them are in Europe and large areas in other parts of the earth are without observatories. Those operated by the

Coast and Geodetic Survey are well distributed, being in Porto Rico, Maryland, Arizona, Alaska and Hawaii, and those operated by the Carnegie Institution of Washington are in Peru and Australia. There is a definite trend on the part of European countries toward placing observatories in colonies so as to produce a better distribution.

However, even though conditions might be improved in certain ways, there is at hand a mass of accurate material on which to base studies. The first method of attack is the statistical, especially the correlation of magnetism with other phenomena. This is the field of the mathematician and his work is of fundamental importance. The mathematician can accomplish much, but he has to guard himself from the temptation, in treating complex physical phenomena by mathematical analysis, of thinking that he is explaining the physical facts while he may merely be fitting the observed facts to his preconceived ideas. It is not unlikely that this has been done in some cases.

However, it is to mathematical analysis that one of the most outstanding of the many contributions of L. A. Bauer and his colleagues of the Carnegie Institution is due. This is the accepted hypothesis that the greater part of the magnetism is due to causes within the earth and only a small portion to outside causes. Another very interesting and important investigation by the same organization is the correlation between sun-spots and magnetic storms. The results of this investigation (Fig. 9) are especially interesting in that, while the correlation over a period of years is good, individual storms occurred without sun-spots being visible and sun-spots have appeared unaccompanied by magnetic storms. A recent example of the latter case occurred in January, 1930, when with sun-spots of notable size and extent

FIG. 6. ARRANGEMENT FOR RECORDING ACCURATELY
THE TIME OF OSCILLATION OF A MAGNET, BY LIGHT SOURCE, MAGNETOMETER AND PHOTO-ELECTRIC CELL.

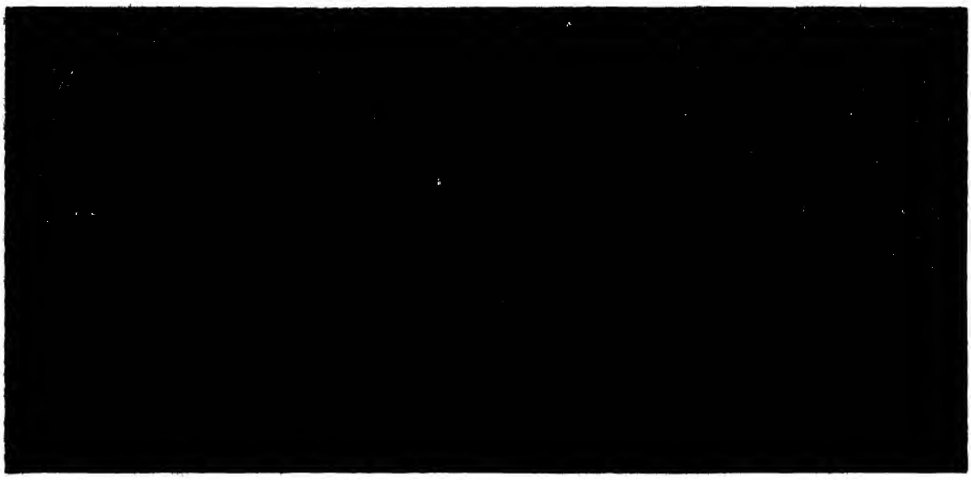

FIG. 7. MAGNETOCHRONOGRAM
OBTAINED AT CHELTENHAM MAGNETIC OBSERVATORY SHOWING RECORDS OF TIMES OF OSCILLATION OF A MAGNET.

there were no magnetic storms of importance. However, all large magnetic storms seem to be associated with sun-spots. It appears that we are dealing with some common cause of both phenomena.

Knowing the close relation between magnetism and electricity, it is an obvious question whether there is any relation between the earth's magnetism and lightning. It is probable that no relation can be traced, but this is not true of the other forms of atmospheric electricity. Here there are correlations over long periods, but when we investigate more closely the difficulties are more serious than in the case of sun-spots. The following statement by Mr. John A. Fleming, acting director of the Department of Research in Terrestrial Magnetism of the Carnegie Institution of Washington, in regard to potential gradient brings out a very important difference from terrestrial magnetism, whose diurnal variation is directly related to the position of the sun:

The electrical pressure in the atmosphere results from the electric charge which exists upon the earth. The discovery of the source of maintenance of the charge is an important objective in research in atmospheric electricity. The average pressure-difference between the earth's surface and a point one meter above it is about 130 volts at sea-level.

On a "normal" day (see Fig. 10), defined as one with cloudless sky, moderate and steady breeze, clear air and high visibility, the electrical pressure varies over a small range and progresses gradually and slowly. The continuous photographic records of this "normal"-day variation obtained thus far during Cruise VII indicate again that its maximum and minimum occur simultaneously over the whole earth. Fig. 10 shows the mean diurnal-variation curve obtained from photographic records on twenty-one days made aboard the *Carnegie* during eight days, August 11 to 24, nine days, September 5 to 16, and four days, October 5 to 8, 1928, while the vessel was in the north Atlantic Ocean. These data apply for mean latitude 18° north and longitude 308° east. They are plotted in Fig. 10 according to local mean time; if referred to Greenwich mean time, it will be noted that the maximum is at about twenty hours, thus in agreement with the conclusions resulting from the earlier work of the *Carnegie*.

On a "disturbed" day, defined as one with low clouds in a partly cloudy or overcast sky, with a complete calm or a high wind bringing with it sand, dust or smoke, or with mist, fog, hail, rain, thunder, lightning or snow, there are frequent and rapid departures covering large ranges from the "normal" variation; the record for such a day is shown by Fig. 11 made

on the *Carnegie*, September 1, 1928, latitude 9° north, longitude 36° west.

Fig. 12 shows the simultaneous predominant twenty-four-hour wave as obtained on board the *Carnegie* over all oceans during her cruises 1915–21, and by the *Maud* expedition, "Drift-ice and Arctic-coast Observations in the Three Winters 1922 to 1925" (north of Siberian coast and off Siberian coast).

Earth currents which sometimes become known at times of great magnetic storms, when they may seriously interfere with telegraphic communication, are usually small but always present. They have certain, but only partial, correlations with terrestrial magnetism.

We now bring into the picture one of the most striking of all natural phenomena, the aurora. The magnetician does not look upon the aurora as a display but as a scientific phenomenon, not only in itself to be explained but to be used as a key to explain other phenomena. Its exact nature is not yet known, but it evidently is a form of penetrating radiation from outside the earth into the upper atmosphere where it becomes visible. It is probably the atmosphere that prevents the aurora from reaching the earth. Accurate measurements by Stormer and others in Norway and elsewhere, made by photographing the aurora against the stars at two places simultaneously, show that for the forms which approach closest, the lower edge is usually on the order of one hundred kilometers from the earth.

In the zones of maximum auroral frequency in the Arctic regions displays may or may not be accompanied by marked magnetic disturbances. When the displays extend far toward the equator they are invariably accompanied by

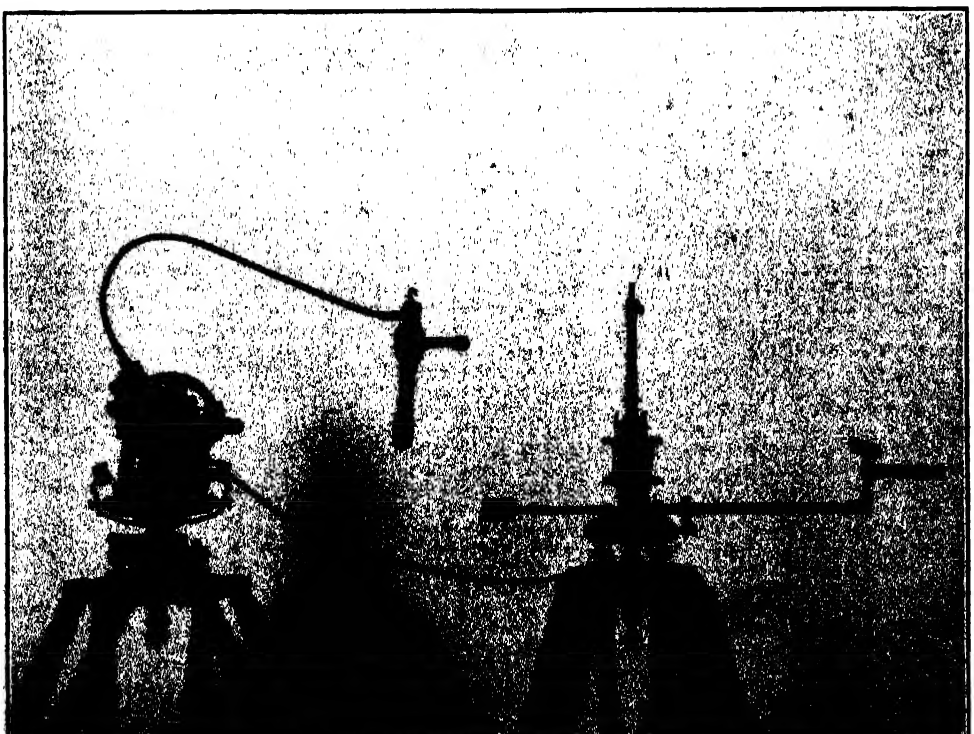

FIG. 8. EARTH INDUCTOR AND GALVANOMETER FOR USE IN DETERMINATION OF MAGNETIC DIP IN THE FIELD.

magnetic storms and usually by strong earth currents. Here we have well-determined facts with which to test theories.

Further progress in the study of the interrelations of terrestrial magnetism, atmospheric electricity, earth currents, the aurora and solar phenomena will depend somewhat on the extent to which it will be possible to make simultaneous observations of two or more of the phenomena at the same place. There is not yet as much of this as there should be, but there is a pronounced trend in this direction. Such activities within or originating within the United States include: Magnetism, atmospheric electricity and solar observations at Tucson, Arizona (U. S. C. and G. S.; C. I. W.; Desert Sanitarium, University of Arizona); intensified solar observations at times of magnetic storms (Mount Wilson Solar Observatory); auroral observations at Fairbanks, Alaska, with magnetic observations at Sitka (Alaska Agricultural College and School of Mines, Rockefeller Foundation, C. I. W., U. S. C. and G. S.); magnetism, atmospheric electricity and earth currents (C. I. W. observatories in Peru and Australia); magnetism, atmospheric electricity and aurora, Antarctic continent (Byrd expedition, C. I. W. cooperating). This last is of unusual interest because of nearness to the magnetic pole.

We now come to a field where the correlations are of unusual interest and importance and one where the element of mystery and as yet unsatisfactory solution is comparable to magnetism—the field of radio transmission. Radio transmission around the earth is accounted for by the hypothesis of what is generally known as the Kennelly-Heaviside layer, an ionized layer far above the earth which serves to reflect and refract the radio waves so that not all the energy can pass off into space. Studies made by

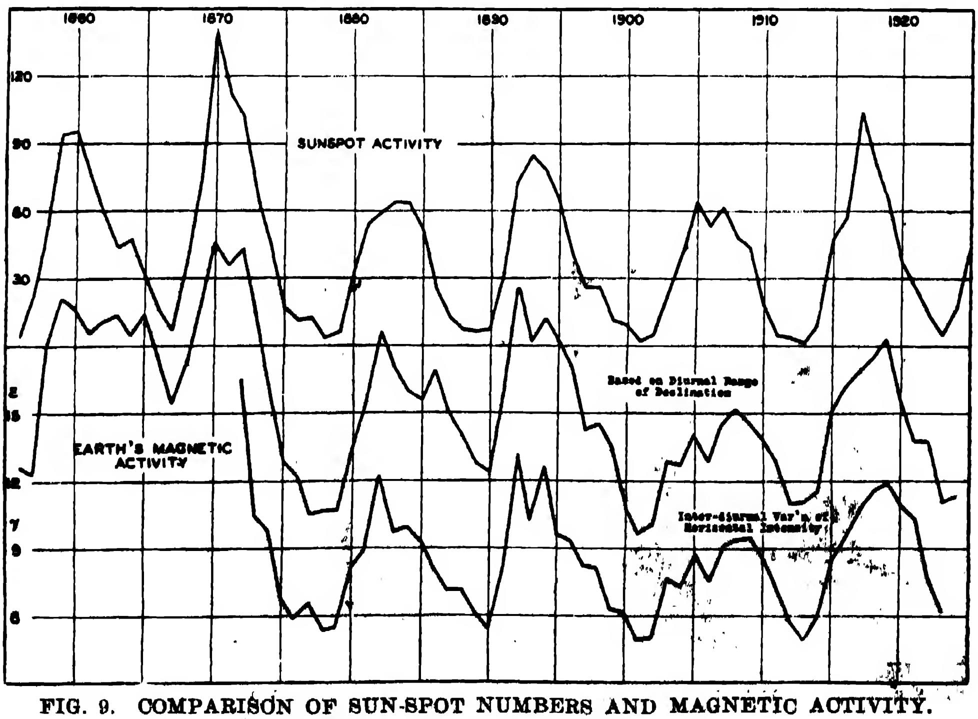

FIG. 9. COMPARISON OF SUN-SPOT NUMBERS AND MAGNETIC ACTIVITY.
Terr. Mag. and Atmos. Elect., MARCH, 1926.

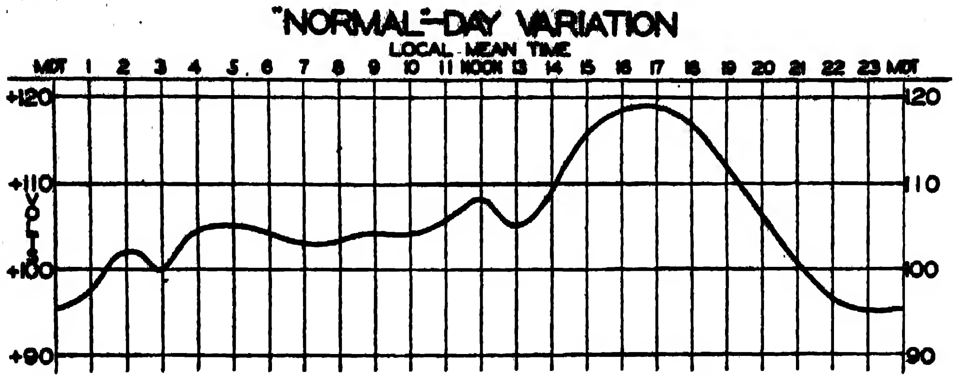

FIG. 10. NORMAL DIURNAL VARIATION OF POTENTIAL GRADIENT OF THE EARTH'S ATMOSPHERE.

various physicists indicate that the conditions are very complex. The reflection is not ordinarily of the clear and sharply defined order of that of light, though it is definite enough for determination of the height of the layer by recording the time difference between the direct wave and that reflected from the layer. The height of the layer has been found to be different at different times of the day, and sometimes it apparently fades out at one height and comes in at another with some overlap. It is generally accepted that the phenomena of fading and skip distance are due to conditions in this layer which cause interference in the waves. Important work along these lines has been done by the Naval Research Laboratory, Carnegie Institution, General Electric Company and others.

The interesting and important fact is that such regularity of behavior as the layer may have is completely upset by a magnetic storm. In general, the height during a storm is much greater than normal and this has the result of changing skip distance conditions, that is, stations normally not receivable under given conditions come in strong while others ordinarily easy to get become impossible. The statement has been made by one of the investigators that with accurate measurements of radio reception it becomes possible to determine the magnetic character of the day almost as well as from the magnetic records. Plans are being developed by a committee of the International Scientific Radio Union for daily broadcasts from the United States of magnetic, atmospheric electric and solar conditions to aid the investigators of these problems, and similar broadcasts are already being made in Europe.

There are many lines of attack on the broad problem which can not be described. Spectroscopy is being found helpful in the study of the aurora and in deducing conditions in the upper atmosphere. The characteristic green line in the aurora has been accounted for and has been found to be present in the night sky everywhere. New ideas are being tried out which, though as yet without definite result, may at any time produce results of fundamental importance.

Many theories have been advanced to explain terrestrial magnetism, but it is impossible in a limited space even to enumerate them. An important effort of considerable promise is being made in the United States in the field of photoelectricity and ultra-violet radiation. Among the workers in this field are

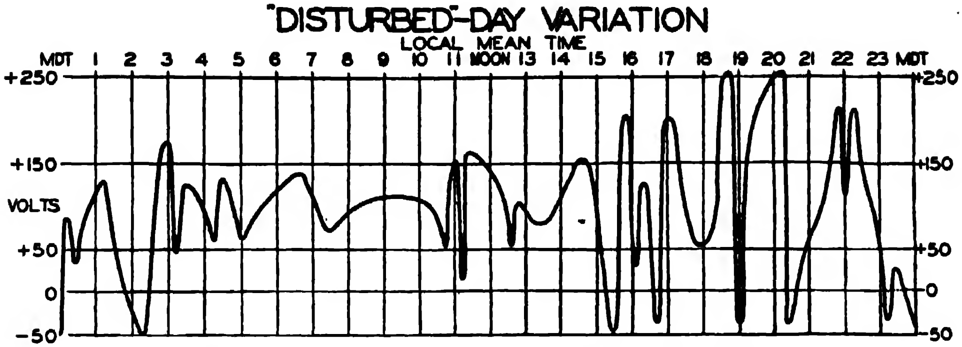

FIG. 11. VARIATION OF POTENTIAL GRADIENT OF THE EARTH'S ATMOSPHERE ON A DISTURBED DAY.

Messrs. E. O. Hulburt and Ross Gunn, of the Naval Research Laboratory.

This theory in a general way is that all the phenomena are produced by ionization of the upper atmosphere by ultra-violet radiation of the sun. Normal radiation is associated with normal conditions, and the ionization of the upper atmosphere sets up a system of currents which are capable of producing results which agree in a general way with observations. Abnormal conditions, such as magnetic storms, wide-spread aurora and increased earth currents are, according to this theory, associated with flares of ultra-violet radiation. These flares produce an unusual number of ions in the upper atmosphere and their interaction with ions present sets up a special system of currents which seem competent to produce the effects observed.

The statement has recently been made that this theory gives values for that part of the magnetism which comes from outside the earth which are in good agreement with those already mentioned as resulting from mathematical analysis of magnetic observations.

From past experience it must be expected that many theories will be advanced before one is found which will fit all the facts. There must be a process of development of correlations, test of theories and rejection or acceptance in whole or in part, and each attempt will advance knowledge.

From the commercial view-point perhaps the most important of all applications of terrestrial magnetism is the study of the upper layers of the earth's crust by magnetic methods. There is no part of the earth where the magnetic distribution is absolutely uniform over large areas, but for most of the earth there is some approximation to uniformity. However, many parts of the earth are magnetized locally, and resulting irregularity of distribution may vary from small amounts to wide-spread magnetic fields which do not at all resemble the normal field. Certain minerals, notably magnetite, and all volcanic materials are magnetic. There is an interesting situation on the island of Oahu, Hawaiian Islands, where there are only a few places where the magnetic observations do not vary with slight change of position of the instruments because of the strong magnetization of the volcanic rock. There are, however, a number of places where, since the volcanic rock is overlaid with beds of coral, the distribution for a limited area is reasonably uniform, but when the values obtained at these places are plotted on a map it is seen that they do not fit into any scheme of uniform distribution. The magnetic method of geophysical prospecting is in effect the

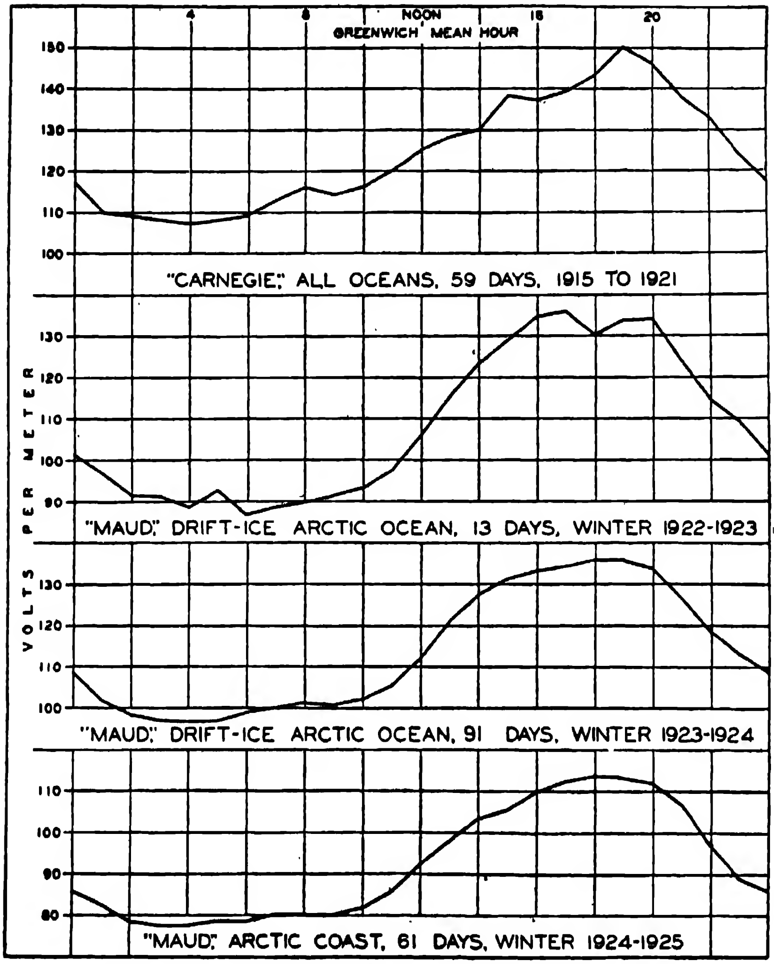

FIG. 12. VARIATION OF POTENTIAL GRADIENT OF THE EARTH'S ATMOSPHERE FOR DIFFERENT LOCALITIES.

determination of local differences from the earth's field as measured at a reasonably undisturbed place in the vicinity. The most successful results have been in the case of magnetite and in tracing formation known to be associated with oil. The magnetic method has its limitations, but it is very generally used as it is the least expensive and so lends itself to preliminary examination of an area of considerable size. Indications found by this method are frequently developed in detail by other methods.

I have indicated that, as a result of the use of the earth's magnetism in navigation of sea and air and in surveying, accurate observations have been made which serve as a basis for investigation of the nature and cause of the phenomenon. There are other phenomena which are directly associated with it and which may be part of one great system. All these different phenomena are being studied separately and together, but in spite of the best efforts of mathematicians and physicists, and in spite of use of all the resources of modern physics, we are still at the threshold

of knowledge, and are yet far from complete understanding and ability to predict future conditions with accuracy.

In order to understand the laws—and there must be definite laws—there must be long-continued accurate observations, preferably of several of the phenomena at the same place. The study of radio transmission has proved that this is intimately related with terrestrial magnetism, and at the same time the necessity of solving the radio problems helps to provide the impetus needed and a new means of attack for the magnetic problem.

Engineers are not accustomed to undertake problems for which the complete solution is so far ahead; they like to see definite prospect of successful outcome of an investigation. It seems to me that this is assured unless the changes which have been discussed are the result of what might be called solar weather, in which case prediction is not likely to become very accurate. It may be that a point will be reached beyond which it will be impossible to penetrate, but no magnetician is willing to acknowledge that this can be the case.

Except in the case of radio, the investigations thus far made have served most of the practical needs, though prediction would be extremely useful and saving in cost. I wish to call attention again to the fact that the records obtained for known practical purposes have proved useful in two new fields of even greater importance from the commercial viewpoint, geophysical prospecting and radio transmission. Engineering research is well established on the basis of immediate or early financial return. Just as in many other fields of physics, it has been shown in the field of terrestrial magnetism that investigations started for a definite purpose have produced wholly unanticipated results. The time will come sooner or later when engineers will have to engage in research which has no immediate prospect of financial return, and they are not unlikely to find that they will make discoveries that bring even richer return.

ANTARCTICA[1]

By Dr. ISAIAH BOWMAN

DIRECTOR OF THE AMERICAN GEOGRAPHICAL SOCIETY, NEW YORK, N. Y.

I

An invitation from the American Philosophical Society is a command. As a member of this oldest learned society in the United States it is with great pleasure and a sense of high obligation that I address you upon invitation of our president. While the new hall will provide safer quarters for the future you will permit me to express heightened pleasure in speaking in the old hall built 141 years ago with the money raised by Benjamin Franklin and his fellow members and business friends, and thus to meet with you among these priceless scientific and historical possessions contributed in the past by an extraordinarily distinguished body of men that includes the names of George Washington, Thomas Jefferson, Charles Darwin, Theodore Roosevelt, Andrew Carnegie and Woodrow Wilson.

Among a membership pledged to "the mutual communication of their discoveries," as the original charter of 1780 puts it, there can not fail to be great interest in the Antarctic Continent, the seventh and last to be explored. That interest is heightened no doubt by the defiance with which Antarctic elements obstruct the inquisitive spirit of man. In the magnitude of the forces of ice and wind and encircling water and that "sullen barrier" of pack-ice that guards the outer seas of Antarctica, it is as if we had a transplantation of some great cosmic agency that has wrought a continent of incredible inhospitality at the South Pole as a symbol of outer worlds of mystery beyond the reach of man.

This is not fancy merely, but rather the result of sober scientific reasoning. Reflecting on the great contrast between the north and south polar regions, the one a hollow, the other a hump, Chamberlin speculated on the possibility that we have in these and other lineaments of our earth actual birthmarks, as we may call them. He saw in the assembly of materials of which the earth is composed traces of the original bolt of matter shot out from the sun to make the infant earth. The core was built up of heavier material at the end originally toward the sun and of lighter material at the end away from the sun. The heavier Antarctic end was further shaped into the southern hemisphere while the lighter materials became the ring of land that lies chiefly in the northern hemisphere. This might be called the ring of life because it made that wide belt of dry land upon which the higher types of life emerged that reached their climax in civilized mankind.

I can imagine Franklin asking Chamberlin why it is that science is so greatly interested in the Antarctic. And I can see Chamberlin pointing to the two unlike ends of the earth. "Here," he would say, "is the north-polar hollow which an echo depth-sounding made in 1927 by Captain Sir Hubert Wilkins, at a point 500 miles northwest of Point

[1] An address before the American Philosophical Society in Philadelphia, February 7. The first part of the address was broadcast by Dr. Bowman and transmitted by short wave to the three explorers now in the Antarctic. That same evening the following radiogram was received by Dr. Bowman at the Philosophical Hall from Admiral Byrd *via* New York *Times:*

"Heard most of your talk quite clearly and enjoyed it immensely. Best wishes to you old fellow from myself and all the gang. Have radioed direct to president American Philosophical Society about invitation to speak. [Signed] Dick Byrd, Little America."

The second part of the address was illustrated with wall maps and lantern slides.

Barrow, Alaska, showed to be over 17,000 feet deep; while at the south-polar end you see plainly a huge protrusion, the Antarctic Continent, bearing mountain ranges over 10,000 feet high which rise from a platform itself 15,000 feet above a ring of encircling ocean deeps.''

The life of the two ends of the earth is as unlike as the topography. The ring of land about the Arctic Basin has yielded fossils in comparative abundance and, together with the abundance and variety of the plants and animals of to-day, makes possible rather definite conclusions about the migration of species from continent to continent in the subarctic zone. No such definite conclusions can be formed in the Antarctic. Exploration must go much farther before the Antarctic chapter can be written. Indeed, Antarctica is still so great a mystery that were a fossil marsupial to be discovered there the event would excite scientists probably as much as direct radio communication with Mars.

Were Benjamin Franklin, the founder of the American Philosophical Society, to hear such a conclusion he would never ask, "What is the good of exploration?" In fact, he could not have raised doubts about the value of inquisitiveness in any form under any circumstances. When a scoffer, knowing Franklin's interest in balloons, asked, "What good are they?" he answered, "Of what good is a newborn babe?" and then went on to contribute money to aeronautical experiments, never missing a balloon ascension if he could manage to attend. The man who sent his kite into the clouds to ask questions of the lightning was one of the founders of what we might call the brotherhood of curiosity. Its members want to know nothing less than all that there is to know about this amazing universe.

It is that driving curiosity about scientific problems still unsolved that has moved Byrd and Wilkins and Mawson to match Antarctic defiance with calculating skill and courage. It was curiosity, paired with technical training, that led to the development of radio communication and, as a result of that curiosity, it is possible to stand here and be heard by Byrd, while at the same time Wilkins and Mawson, thousands of miles away, may hear the same message.

Admiral Byrd, I have been asked by President Dercum to send you a personal message from the American Philosophical Society. He has asked me to say how deeply moved we all are by the reports of your expedition, how interested in its success, how anxious over its safe return. You have gained results not of scientific worth merely but of deep interest to all mankind. President Dercum has asked me to invite you to address the society upon your return that the officers and members may hear from you directly. What I have to say in the address that follows this brief radio introduction will be chiefly through the medium of twenty or thirty maps that summarize the results of your expedition and those of Wilkins and Mawson. You have no conception how personal to each of us your affairs have become. Morning, noon and night we wonder about the state of the ice—will it open in time, can the *City of New York* get through? When that ship was about to sail from New Zealand a few weeks ago there must have been many who recalled Arthur Colton's lines:

> And one ship in port to-day
> On the morrow
> Southward bound will far away
> The swift sea furrow;
> Whom the loud Antarctic waits
> And frozen citadels with creaking gates.

Our invitation is no less warm to Sir Hubert Wilkins and Sir Douglas Mawson. Through special arrangements this message goes directly to you both and as a personal friend of both I want to say with what deep admiration I follow your fortunes and wish your gallant enter-

prises success. I know that Admiral Byrd shares and often expresses equal admiration. And when the time comes for you to communicate your results to this learned society I feel sure that the admiral will be here to lead the discussion. It would gratify this assembly if within the next few days we might have acceptances to these three invitations to meet in this old hall and hear "the mutual communication of your discoveries."

All three of you have brought the Antarctic to the clubs, the schoolrooms, the family firesides of millions the world around. Would Gould succeed in finding the coal layer he was after? The question got to be a poignant one! Would Wilkins find the base he sought? Where would the ice halt Mawson? We have found ourselves involved in an "Antarctic series," with this curious condition, that everybody is betting on the success of all the teams, the three we have mentioned and the Norwegians, particularly our old friends, Major Isachsen and Captain Riiser-Larsen. This wide interest we owe not only to yourselves but to the newspapers, and the time has come when science as well as the general public should acknowledge its indebtedness to the press. Without the assistance of the newspapers the well-equipped expeditions of recent years could not have been undertaken. However efficient aeroplanes may be, they are expensive things. Moreover, we are far more interested in an expedition from which we can have almost daily radio reports than we are in one that vanishes for several years, returns with news that blazes for a week and then drops into the gulf of forgetfulness. But for the extraordinary support of the New York *Times*, which includes a triumph in radio communication, Byrd's expedition would have been impossible and public interest in it short-lived. The *Times* has contributed in this way not merely to public interest, for which it has no doubt already gained some measure of reward; it has gone far beyond this and made a contribution to science as substantial as many a scientific institution. In the same spirit the Hearst newspapers have supported Wilkins, helping him with his equipment, maintaining radio communication and assisting in the publication of his results. This group is also supporting the expedition of Sir Douglas Mawson. It is but fair that we take a moment from the consideration of the scientific results of three major Antarctic expeditions to praise these two newspaper agencies for the public-spirited way in which they have gone beyond commercial objectives and made direct contributions to scientific discovery.

But if science is to reap the full benefit of the opportunities thus thrust into its hands the scientific side of the story should be as well presented as the popular side. To this end the American Geographical Society of New York has for some years attempted the constructive task of publishing a series of books and maps of direct value to the explorer in the field as well as to scientists and laymen at home. It is extraordinary that this has not been done in the past quarter century. The explorer in the field has had to turn from one map to another. In a series of Arctic and Antarctic maps on different scales the society has brought together original surveys and meteorological and magnetic data so that the field operations might be planned upon a large base map. Our bathymetric map of the Antarctic is the only one of its kind in existence that shows the present status of our knowledge of Antarctic submarine relief on an adequate scale.

At the same time the society prepared two volumes which expedition leaders have described as an explorer's bible—"Problems of Polar Research" by thirty

contributors, among whom are included practically all the leading explorers of to-day, and the "Geography of the Polar Regions," which describes the Arctic and Antarctic region by region. These books and maps pool the knowledge of all polar explorers. They have been put into the hands of trained men on each of the present Antarctic expeditions and have led to the search for particular things, not just anything. Modern large-scale exploration, to be worth its cost, must be scientific, not merely a blind and adventurous wandering into the unknown.

If we look at the Antarctic to-day through the eyes of those who have specialized in its interpretation we shall see the real importance of the present-day search for facts. While there are over four hundred species of flowering plants in the Arctic, some of them luxuriant, there are but two in the Antarctic, and these have a precarious hold at the extreme limit of their range. Both are found on the western side of "Graham Land." One is a grass; the other represents a family of herbs. Both are dwarfed. There are no ferns in the Antarctic. Only local tundras (of mosses and lichens) up to a half acre or more are known. The short summer and the remarkably low temperature (no month has a mean temperature above freezing) is responsible for this poverty of plant life. By contrast, during the warmest part of the Arctic summer the mean temperature is above freezing, and the ground may thaw a few inches in a very few days. From these few indications you see that the present life of the Antarctic is too meager to furnish a basis for wide-ranging speculation concerning past migrations between Africa and South America or between Australia and Africa. The search for fossils is therefore keener than ever because it is chiefly through them that explanations are sought of present distributions of life by migration across the Antarctic region. These are not merely the abstractions of the specialist. The layman can get the sense of it. Did it ever occur to you how remarkable it was a year or more ago to have a whole column in a New York newspaper devoted to the finding of pre-Cambrian fossils by Sir Edgeworth David, of the University of Sydney, Australia?

It is in the rocks of Antarctica that we find the greatest realm of wonders. In earlier periods the life was far more abundant. The whole earth, Arctic and Antarctic included, enjoyed a mild climate in what geologists call the Jurassic period. At that time there lived in West Antarctica the Sequoia, the Araucaria and the Beech. We know this through fossils brought back by explorers. The former range of animals as well as plants is determined in the same way. The value of such records is so great that the search for fossil-bearing rocks in Antarctica has now become one of the major sports of science. That is why Professor Gould attached so much importance to the carbonaceous material in the sandstone from Mount Fridtjof Nansen. Even the contents of the stomachs of seals and penguins have been searched for rock specimens and thus much valuable information has been found about coast-lines where no exposed rock exists. The dredge has brought up from the bottom of the Weddell Sea at a depth of 10,000 feet fragments of Cambrian rocks, and the ice tongues that pour out through the mountain passageways about the Ross depression have borne from distant points limestone fragments of the same age that throw light upon past conditions in Antarctica.

It is the higher forms of life that interest us most, for here we are closer to the background of man himself. Where we now have a highly specialized group of birds of which three are exclusively Antarctic species—the skua, the Adélie penguin and the emperor penguin—

there was once a greater variety. If we include fossil penguins of wider range the number of extinct species already known rises to twelve. It has been suggested that the diminished number of species and their higher specialization to-day were brought about by the advancing ice in a period of glaciation even more severe than the present one, for the ice at the present time has withdrawn from the wider limits it once claimed. If Antarctica to-day seems almost buried in ice, we can only say that in a still earlier period it was overwhelmed.

Many people must wonder why it takes so long to plan a polar expedition. The matter would be simple if the explorer faced perfectly definite conditions of climate and ice. Both pack-ice and weather are never the same two seasons in succession. In spite of all the studies that have been made upon the pack-ice and all the temporary passages that have been traversed we still have very little knowledge about its behavior over substantial periods of time. It presents new problems every year. Admiral Byrd's low-powered ships were able to get through it without special difficulties when the party was deposited at Little America last year, though there were risks and trials enough. This year it is exceptionally heavy and presents a barrier three hundred miles across. Ice of that sort has to be humored, as the sailor puts it. All eyes are upon the month of February. It is then that there is the best chance of penetrating the pack and coming out again quickly. By the middle of March heavy freezing begins again. In varying width, and with breaks here and there, the pack-ice almost encircles the Antarctic Continent, in some places standing offshore for some distance, in others continuous with the ice foot of the land or the discharging ice-cap. Almost everywhere it has to be reckoned with. Mawson faces the problem near Enderby Land to-day. A few weeks ago Wilkins was held off from the land 150 miles north of Charcot Island. Riiser-Larsen, operating near Enderby Land, was able to fly to the edge of the shore ice and make his way to land on skiis, taking possession of a bit of land in the name of Norway.

The American Philosophical Society has as its main purpose "the promotion of useful knowledge." You may wonder what these scientific questions have to do with practical affairs. Of course every one knows that the Antarctic is a great source of whale-oil (used almost exclusively in the making of soap), and we know how extensive that industry has become. Most fortunate it is for the cause of scientific discovery that it pays to catch in Antarctic waters, even if the whalers have been inclined to keep their discoveries hidden as a commercial secret. They have made whale-oil pay for knowledge, combining real exploration (and great hospitality to other explorers) with economic exploitation. This is quite in the tradition of polar exploration. Old whaling captains will still tell you of that knight errant of Arctic whalers, William Scoresby, commander on thirty voyages, who chose the coast of Greenland in preference to Spitzbergen not only because he sought whales but because he had the hope "of making researches on a coast that was almost entirely unknown." He prefaces his surveys with the assurance that "an excellent cargo of whales . . . was obtained," but geography records an indebtedness greater than that of the whale-oil industry in the name "Scoresby Sound" permanently affixed to the map of Greenland.

Whaling itself can not be more than a minor industry at best. Are there larger utilities to be sought in Antarctica? If we ask the question of agriculture in the southern hemisphere the answer is in the affirmative. It would pay handsomely in crops and cattle and security of life if meteorological stations were set up on the borders of the Ant-

arctic and in the island groups that girdle it. If we knew the habit of the "spells" of Antarctic weather there is little doubt that we should be able to find a connection between it and the rainfall and drought periods in the cereal and pastoral lands of Australia, South Africa and Argentina. It is under the impulse of this idea that Captain Sir Hubert Wilkins has carried on his explorations in the Antarctic Archipelago for two seasons. He is not down there just for fun; he is searching for suitable bases for meteorological stations to be established by international cooperation. With a ring of such stations about the Antarctic and with daily radio reports as to the weather, it would be possible to draw charts that would trace the effects of cyclones and anticyclones as they move forward from breeding places out over the southern ocean.

To forecast seasons of drought would be a practical achievement of the highest order, and no less important would it be to forecast seasons of exceptional rain. We have in Australia, Argentina and South Africa great areas of marginal lands where for several years on end it may be too dry to maintain flocks and herds and crops of normal extent. Even in years of sufficient rain the farmer needs warning to enable him to take advantage of nature's bounty. It is not putting the case too strongly to say that the practical benefits of meteorological studies in the Antarctic through the medium of a chain of weather stations outweigh all other Antarctic interests put together. We have had international cooperation for such purposes in both the Arctic and the Antarctic, the former nearly fifty years ago, the latter twenty to twenty-five years ago. But these were periods when we knew far less of the connection between the weather of high latitudes and that of the more habitable lands in which most of us dwell. From both the scientific and practical standpoints it is imperative that such stations be established at the earliest possible moment if we are fully to occupy those pioneer lands of three continents where the risk of loss still holds back settlement or puts a cruel strain upon it.

However briefly I have sketched the scientific problems of polar lands I hope that you see in polar exploration not adventure merely but serious business pursued for definite reasons by those rare men who combine physical courage and strength with scientific imagination.

II

Exploration is somewhat like a military campaign. This is especially true in a territory so formidable as the Antarctic in size and in climatic severity. The first thing is to make a reconnoitering attack to get the outlines of the situation. It may seem like a very simple object, that of going out to map the border of the Antarctic Continent, but until this is done no one may safely conduct a long campaign in the interior. It was wise planning for Byrd to base his flights on the Bay of Whales at the edge of the Ross Shelf Ice which placed him more closely to the Pole than he could get elsewhere by ship and where he met conditions fairly well known from previous explorations. In a similar way Wilkins based his operations on Deception Island where he could depend upon the help of the whalers and from which he could explore that long finger of Antarctica which stretches up toward South America. For two seasons he has been searching for a base as reliable as Little America from which he could take off with a full load for the more than two-thousand-mile journey to the Ross Sea.

In geography we attach very great importance to this first stage. When the outlines of the continent have been mapped and the position of the offshore islands determined, when we have photographs of the coastal features and

know the habits of the pack-ice that all but surrounds the continent, when we know the location and width of the shelf ice that fringes the shore in places, when the habit of the winds is better known—then the more intensive studies at critically selected points will be vastly more profitable.

Right here we have a most important fact in polar work, that the pack-ice is never the same two seasons in succession, because the temperature varies, the force of the wind is variable from year to year and there are corresponding effects upon the currents. Very much useful work remains to be done upon the pack-ice itself. Until we can establish its habits we can not plan wisely with respect to the critical points of attack in the course of future expeditions to the still unknown sectors of Antarctica.

We take aeroplane and radio so much as a matter of course that it is only occasionally that we realize what they mean in speeding up the reconnoitering stage of polar exploration. Until November 16, 1928, no aeroplane had been flown in the Antarctic. On that day Wilkins made his first flight from Deception Island. Compasses and other instruments have been immeasurably improved. Sounding devices are now in course of construction for operation from a speeding airship. Canned heat as well as food can be carried. There need be no fear of starvation or scurvy. Byrd timed his flights along a meridian in a short period of clear weather on both his north and south polar expeditions. A vast amount of work can be done with present-day instruments in a single spell of good weather. Wilkins' flight over "Graham Land" was likewise timed by the weather. On his great flight from Alaska to Spitsbergen, he spotted a storm far ahead and flew around it, thus maintaining his visibility and making certain of his position. The radio enables one to learn the precise time and has become an important element in position finding besides vastly increasing the security of the polar explorer. He can be in constant communication with sources of information at home. On several occasions the American Geographical Society has been requested to supply, by radio, technical information concerning maps and soundings for the Byrd expedition, as it did for Wilkins before his Barrow-Spitsbergen flight. As new conditions arise the explorer in the field can now call upon the scientist at home for advice and assistance. He can command resources as quickly as if he had the advantages of a post office or a telegraph station at hand. The possibilities of such collaboration in the future are very great, since the explorer in the field can obtain information and advice which were totally inaccessible to his predecessors.

Unquestionably the most important information in the reconnaissance work that represents the first stage of exploration is gathered by the camera operated from the aeroplane. By this means there have been outlined in two seasons by Wilkins practically the whole of the hitherto unknown portion of the Antarctic Archipelago and the coast of Hearst Land for several hundred miles. Byrd has photographed a stretch between Little America and the Pole and has added a large piece of territory east and northeast of Little America which includes a newly discovered mountain range, as well as Marie Byrd Land and the Rockefeller Mountains discovered last year. When these photographs are built into a mosaic and reduced to a map we shall have substantially a topographic base map from which later operations may be planned into the still undiscovered country on the east.

Every subsequent explorer will have his way made easier by such precise information. In addition, we shall be able to see the relation of mountain to mountain and build up those hypotheses

which will lead to better planning in the search for critical information that still remains to be found before we can complete our picture of the form and build of the Antarctic Continent. This is the way of science. A new discovery is not an end to anything. It is a step in an unhalting advance that began when speech and fire and the spear and the floating log were no longer mysteries to awakening man.

Broadly speaking, there are two areas of greatest interest from the standpoint of reconnaissance work. The first is the tracing of the depressions of the Ross Sea and the Weddell Sea to their heads in order to determine if there is a salt-water connection right across Antarctica, thus making a great island of the territory between Little America and Hearst Land, or possibly a group of islands. Both Byrd and Wilkins hoped to carry their flights inland far enough to determine this point, which was among their announced objectives. But neither has succeeded in doing more than continue the probability that these two depressions run farther inland than we had been led to expect. Most significant is the discovery of Gould that the Ross Shelf Ice extends at little elevation above sea-level, past the 150th meridian, and swings eastward along the front of the Queen Maud Range farther than we had been led to expect from the reports of Amundsen, whose Carmen Land now drops out of the map. Even if a salt-water connection were found to exist it is altogether probable from the slight elevations already determined at the heads of these depressions and from the soundings on the border that the connection is ice-filled throughout. And if an archipelago exists to the northward of this depression the separate land units are probably "welded" together, to use Mawson's term, into a single unit continuous with the larger part of the continent bisected by the 70th meridian east of Greenwich.

Two great objectives are the determination of the position of the coast-line between Enderby Land and Coats Land and from Hearst Land to King Edward VII Land. The flights of Byrd and Wilkins have cut off six hundred miles of hitherto unknown coast along the southern Pacific Ocean, reducing to 1,600 miles the unexplored section. The Coats Land-Enderby Land coast is of equal length and is succeeded by another stretch half as long east of the 50th meridian.

In the field season 1928–29, after establishing himself at his camp at Little America, Byrd undertook a flight to the northeast as far as Alexandra Mountains, from which he flew south to discover a new range which he called the Rockefeller Mountains. On a second flight past the southern end of the Rockefeller Mountains he discovered high land beyond the 150th meridian west which he named Marie Byrd Land. Fortunately, it was possible to make a second flight the same day with the aerial mapping camera and thus to provide the basis for a detailed map; and later on Dr. Laurence Gould, the geologist of the expedition, flew to the Rockefeller Mountains and collected rock specimens.

In the season just closing, Admiral Byrd has been able to make a number of flights of which two are of outstanding importance. A first was made on November 28 and 29, 1929, when again the aerial mapping camera was employed on an eight-hundred-mile flight to the Pole. The round trip of 1,600 miles was made in nineteen hours, including a stop of one hour at a refueling base. Of importance to the success of the flight was the radio report on the weather as far as the foot of the mountains over four hundred miles from Little America, made by Dr. Gould's geological party. In return Byrd was able to help the geological party by dropping a package of photographs taken on a previous base-

laying flight, thus enabling Gould the better to plan his advance to his distant goal, Mount Fridtjof Nansen and the Queen Maud Range. Byrd's second flight was intended to extend his discoveries toward the east of Little America while at the same time he established an independent communication with the sea-coast outside of the Ross Dependency. In this manner he was able to set up the basis of an independent claim on the part of the United States to newly discovered territory tied directly to the coast.

It was his good fortune to discover a deep salt-water entrant on this flight which seems to cut off King Edward VII Land from a new mountain range extending along the 147th meridian west, to trace one hundred miles of new sea-coast and to connect the new mountain range with Marie Byrd Land in the interior, thus providing the framework for a physiographic description of an entirely new group of topographic features. At the same time the trend of the newly discovered coast throws light upon the hitherto baffling question as to why there should be such a great concentration of ice in the Ross Sea and in the region to the northeast. The whaling operations of the Norwegians have shown the pack-ice thereabouts to extend far to the north as if it were held back by land still untraced or by groups of islands that might serve equally well to confine the ice in the direction of the Ross Sea.

The sledge party under Dr. Gould which had Mount Fridtjof Nansen as its objective was able to explore new territory and at the same time gather rock specimens from localities so close to the Pole that both rocks and fossils have exceptional value in determining the probability or improbability of a connection between the Queen Maud Range and the Antarctic Archipelago. New hypotheses of origin may thus be set up that will help direct future explorers in their search for additional information. From 6,500 feet elevation on the flank of Mount Fridtjof Nansen, Gould found a sandstone that includes a layer of carbonaceous material, thus extending to this distant interior point the so-called Beacon sandstone found at other points in the long stretch of South Victoria Land on the west side of the Ross Sea, and making it more probable that the south polar plateau, east of the 160th meridian east, is underlain by a vast coal field.

Wilkins' great flight from Deception Island, six hundred miles south, on a meridional course, is one of the great feats of exploration by aeroplane in the Antarctic. In five and a half hours of outward flying he transformed our whole conception of so-called "Graham Land," proving that it was broken into separate units and that as a whole it was separated from the main body of the Antarctic Continent by scattered islands and a water passage filled with ice. The name "Graham Land" thus drops off the map and the whole group of islands may more properly be designated the Antarctic Archipelago. Through his photographs from the air and the positions indicated on his route it was possible to construct the outlines of the eastern coasts of the main islands composing the archipelago as shown in the July, 1929, number of the *Geographical Review* and as reproduced upon the map accompanying that issue.

It was a most startling and important discovery that Sir Hubert had made, and it is a great satisfaction to record that in the present field season he was able by a short flight from a base on the western border of the archipelago to check his determinations of last year and show the substantial accuracy of the positions indicated upon the map that originally appeared in the *Geographical Review*.

In addition, he carried out a four-hour flight on December 31, 1929, which enabled him to trace what appears to be

the mainland of the Antarctic Continent westward just south of the 70th parallel as far as the 80th meridian. He took off from the water beside the *William Scoresby* at 67° 47′ south and 75° 21′ west. On this flight he proved the insular character of Charcot Island, and photographing the island and the mainland shore and observing the trend of the shore east and west he was able to connect with his discoveries of last year and establish the relative positions and relationships of the Antarctic Archipelago and mainland in a manner invaluable to future exploration and very gratifying to the cartographer.

Upon the other side of Antarctica there is an expedition of which we shall hear much more before the end of another year. It is conducted by Sir Douglas Mawson and sponsored by the governments of Great Britain, Australia and New Zealand. As on his previous expedition of 1911–14, Mawson proposes to explore that part of the Antarctic border that faces Australia as well as the section between 50° and 80° east. He hopes to make studies on the continental shelf that will be primarily oceanographic in character. His ship, Scott's old *Discovery,* is equipped with modern apparatus for oceanographic work. He expects to take a large number of soundings on the continental shelf; determine the outer border of that shelf, which is, in fact, the outer border of the continent itself; investigate the physical and biological features of the water overlying the continental shelf, and make such studies of sea organisms and sea floor as will throw light upon the origin of the continent as well as the distribution of life in a manner that may be useful to the whaling interests. He has an echo depth-sounding machine as well as a drum and cable for making soundings of the conventional type. He will secure bottom and water samples and, by means of a small scouting plane, has planned flights from the ship over the ice fringe in order to determine, if possible, the outlines of the coast hitherto unseen over much of the section that he expects to explore.

Mawson has already done important work. He has gone by way of Cape Town, Possession Island (one of the Crozet group), and thence south to a point in the ice-pack about on the 75th meridian east, being held off from the land by heavy pack-ice. The soundings becoming shallower, a flight was made in the scout plane on December 31 from 66° 11′ south and 65° 10′ east, and on this flight, beyond a forty-mile belt of unbroken ice and ten miles more of coastal water, there were sighted what appeared to be low, hilly, ice-covered tracts of land.

Mawson's concentration upon the continental shelf is in line with the most advanced geologic thought concerning the meaning of this shelf and the life found in the waters upon it, in the recent up and down movements of the Antarctic Continent and the heavier glaciation that preceded the present stage of ice retreat. Though the land life is poor, the shallow water life about the rim of the Antarctic is amazingly rich. Owing to the upwelling of the deeper waters near the shore, as the strong winds brush the surface waters away from the continent, there is brought from below the deeper oceanic waters rich in nitrogen. The coastal waters also contain an abundance of silica owing to the low temperature and to the large quantity of rock waste swept down by individual glaciers as well as the Antarctic ice-cap. There are 0.5 parts per million of nitrogen in Antarctic waters in contrast to the 0.15+ parts per million in the North Atlantic and 0.10 in tropical oceanic waters.

The high nitrogen content of Antarctic waters makes them an ideal home for those immense quantities of diatoms that

furnish the base for higher forms of life in succession. This is the key to that immense development of seals, penguins and whales that excite our curiosity by their appearance in waters adjacent to the coldest, most desolate and most terribly windswept land mass in the world, the "home of the blizzard" as Mawson called it. Mawson saw 16½ acres of penguins in Macquarie Island, half way between New Zealand and Antarctica, and it is estimated that a million penguins were observed in one rookery in the South Orkneys, in latitude 60° on the northern border of Weddel Sea.

No account of Antarctic exploration would be complete without reference to the scientific work carried out, especially in the last few years, by Norwegian whaling interests. Wishing to free themselves from the obligation to pay a license fee to the British government, the Norwegians have steadily developed larger ships capable of maintaining themselves for a season at sea in areas outside those under British jurisdiction. To help them toward an independent status they have annexed Bouvet Island southwest of Cape Town, about on the 55th parallel, and Peter I Island which lies at the edge of the pack-ice on the 90th meridian west of Greenwich, or 10° west of the western border of the Falkland Islands Dependencies. During the last three Antarctic summer seasons four expeditions have been sent out, and in the present season, 1929–30, three Norwegian vessels are in the Antarctic engaged in scientific exploration. Both Major Gunnar Isachsen and Captain Riiser-Larsen are now in the Antarctic in vessels equipped for exploration, and reports have been received of operations between Coats Land and Enderby Land, where fast land has been discovered and "possessed" for Norway. In this they were helped by scout planes, by means of which they were able to fly from their ship one hundred miles to open water from the edge of which they traveled by skiis, raising the Norwegian flag on the shore. The whalers have also skirted the pack-ice west of the Antarctic Archipelago right around to the 140th meridian west, thus making many new determinations of the position of the ice that will be of great value to science when available in published form.

THE PASSING OF METAPHYSICAL IMMUNOLOGY

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I

Our first half century of modern experimental immunology has given to scientific medicine some of the most spectacular clinical victories of all times. No therapeutic triumph is greater than the miracle of diphtheria antitoxin, few diagnostic successes rival the certainty of the Widal serological test for typhoid fever, no surgical boast is more justified than serologically controlled human blood transfusion. This relatively brief period of applied biological research has been characterized by the rise and fall of a half dozen immune theories, condensing into five decades two millenniums of previous clinical evolution.

The initial immunologic theory of this period is usually credited to Pasteur. Pasteur noted that artificial cultures of pathogenic micro-organisms are usually short-lived, rarely remaining viable longer than a few days or weeks. This he assumed to be due to starvation, exhaustion of suitable food material in the culture medium. Applying this exhaustion theory to the human body, Pasteur pictured convalescent immunity as a result of a complete destruction of some necessary bacterial pabulum in human tissues. Assuming that each and every bacterial species has its own highly specialized nutritional needs, and that the necessary chemical factor or group of factors is very slowly or incompletely regenerated in human tissues, this exhaustion theory gave a logical and consistent explanation of all facts of convalescent insusceptibility known during the initial Pasteur decade. With the subsequent demonstration of successful serum transfer of convalescent immunity, however, the specific exhaustion theory became untenable. It was impossible to picture an effective serum transfer of an absent chemical component. Pasteur immunology, therefore, became the first obsolete immunology of the modern era.

II

Pasteur's later contemporaries soon demonstrated, however, that self-limitation of artificial bacterial growth is usually not due to exhaustion of suitable food material but to accumulated bacterial products. A new concept of convalescent insusceptibility was thus suggested, which pictured acquired immunity as a result of retained microbic products or their secondary biochemical derivatives. This retention theory was championed by numerous serologists, particularly by Buchner, with whose name the specific retention theory is usually associated.

Assuming that retained microbic products or their secondary derivatives are very slowly or incompletely destroyed or eliminated from the human body, Buchner immunology was in full accord with all known serological facts of his time. It was an apparently logical corollary to the buchnerian postulate, however, that there must be some constant quantitative relationship between the injected dose of a morbidic agent and the resulting convalescent antimorbidic or protective substance. So paradoxical were the observed relationships between injected diphtheria toxin doses and the resulting serum antitoxin, however, that Buchner himself was convinced of an error in his retention hypothesis, which he, therefore, repudiated. Buchner im-

munology, therefore, became the second obsolete immunology of the modern era.

III

For its third theory, the adolescent science of immunology now turned to the real or assumed facts of tissue physiology. With minds polarized by subconscious ancestral beliefs in warring spiritual forces in the human body and in antagonistic morbidic vital humors, Pfeiffer assumed that the tissues of the first man were endowed with minute samples of specific antidotes against each and every morbidic agent the sons of Adam were predestined to meet, or that a similar plurality of intracellular antimorbidic endowments has resulted from the miracle of evolution. Pfeiffer further assumed an intracellular potentiality of increasing and flooding the human body with these hereditary specific antimorbidic humors in times of need.

For a logical theory of convalescent insusceptibility it was only necessary for him to postulate an effective physiological stimulus for this hereditary emergency internal secretion. Inspired by Pavlov's demonstration of reflex secretion of gastric juice, Pfeiffer found his endocrine stimulus in a postulated highly specialized nerve-reflex. This, of course, was equivalent to assuming a multiplicity of morbidity-recognizing sensory nerve endings in human tissues, or an equal multiplicity of morbid-specific motor nerve impulses. Neither assumption was verifiable by contemporary physiology. Pfeiffer, therefore, in turn, voluntarily sacrificed his reflex immunology on the altar of medical progress.

IV

Pfeiffer's basic faith in hereditary, polyvalent, antimorbidic endocrine endowment, however, was not discarded. Coupled with the new assumption that the immunologic stimulus is chemical rather than neurological, and that the morbidic factor itself functions as an exogenous hormone, the Pfeiffer hereditary immunologic endocrine was endorsed by Ehrlich and in time elaborated by him into what is now known as the "side-chain" theory or "specific receptor" theory of immunity. The characteristic feature of the Ehrlich theory is the assumption that the postulated, hereditary, specific, intracellular, antimorbidic humor is an integral part of the living cytoplasm, a molecular side-chain or sessile receptor, having a specific superavidity for the morbidic agent.

Specific-receptor immunology furnished a logical and consistent explanation of all known facts of immunity at the time of Ehrlich. Flooded with highly avid, desquamated side-chains, the morbidic agent was killed or neutralized in the body fluids before it had time to unite with vital cells. Serum transfer of "free receptors" readily accounted for successful diphtheria antitoxin. Test-tube agglutination of specific microorganisms, precipitation of specific foreign proteins, laking of specific foreign erythrocites and other observed serum reactions were logical results of the assumed chemical avidity of these humoral side-chains for morbidic agents. Varying numbers, avidities and valences of humoral and sessile receptors in different animal species and in different organs and cells of the same species fully explained all known variations in hereditary or natural resistance. Within five years specific-receptor immunology became the international basis for theoretical deductions and clinical applications, which proud position it held for at least a quarter century.

Of course, Ehrlich immunology was not without its critics; but criticism was almost invariably directed against some of its minor, relatively unimportant secondary hypotheses, rather than against its basic concept. Interminable debates as to whether or not the postulated morbidic-antimorbidic avidity obeyed the new-discovered laws of electrolytic dis-

sociation. Prolonged controversies as to whether or not observed inconsistencies with the chemical law of multiple proportion were due to asymmetrically polyvalent receptors or to a plurality of closely related monovalent receptors. Difference of opinion as to whether or not the apparent cooperation of specific receptors with certain normal serum defenses is in the form of their joint attack on the morbidic agent, or a first-wave specific attack, followed by a second-wave non-specific "mop-up."

V

During the first decade of the Ehrlich dominance very spectacular confirmatory evidence was discovered in the newly recognized phenomenon of acquired specific hypersusceptibility, the apparent exact opposite of acquired immunity. This hypersusceptibility is also transmissible by serum transfer. By postulating intracellular proliferation of specific receptors without adequate desquamation into the blood stream, increased morbidic avidity of vital cells could be pictured, without compensatory humoral protection. By assuming that desquamated side-chains are homesick for their cells of origin, and that, transferred to a normal animal, they leave the blood stream to reunite with their mother cells, serum transfer of increased morbidic avidity could be explained. Professional immunologists, however, realized that by this time they were endorsing a theory consisting of no less than twenty superimposed major and minor premises,[1] the most monumental polysyllogism of modern sciences.

While clinicians were pointing with pride to diagnostic and therapeutic successes following logical applications of the Ehrlich concepts, professional immunologists were astounded by the ever-increasing number of theoretical paradoxes and clinical failures. Every diagnostic victory was matched by a score of unpredictable diagnostic failures. Each clinically valuable vaccine was offset by twenty unexpected prophylactic or therapeutic vaccine disappointments. Every statistically valuable antiserum was accompanied by dozens of statistically inert serological placebos. With no Ehrlich-deducted clinical application were the probabilities greater than 1:20 of statistically demonstrable clinical success. Moreover, professional immunology soon found that many apparent successes were purely accidental findings, due to wholly unpredictable collateral phenomena. The Wassermann diagnostic test for syphilis is the outstanding example.

VI

The newly recognized phenomena of specific hypersusceptibility gave laboratory immunology, for the first time, a series of easily recordable physiologic reactions with which the truth or falsity of the specific-receptor hypothesis could be tested: fatal spasmodic closing of the bronchioles, lethal cardiac paralyses, obliterating arterial vasoconstriction, fatal syncopy, explosive abortion, uncontrollable defecation, altered threshold of nerve stimulation, abolition of nerve reflexes, local edemas, changes in total blood volume and altered chemical composition of blood plasma on tissue lymph. A decade of immuno-physiological research gave such a mass of Ehrlich-irreconcilable physiological data that even the most ardent champions of specific-receptor immunology were forced to the humiliating conclusion that for three decades they had dwelt in a world of biological make-believe.[2]

With loss of faith in Ehrlich orthodoxy, there was the still more humiliating realization that for three decades immunological research had directed its main attention away from the particular biological fields whose mastery might have given adequate control of infectious

[1] "The Newer Knowledge of Bacteriology and Immunology," University of Chicago Press, 1928, p. 1098.

[2] Scientific Monthly, 25: 362, 1927.

diseases. Cytophysiology, for example, the basic immunologic field opened by Metchnikoff, only to be abandoned under the Ehrlich omniexplanation of all immunologic phenomena. A dozen Jacques Loebs and a score of years can not compensate for this neglect.

Equal indifference in the immunochemical field, which was equally insignificant to Ehrlich immunology, the postulated morbidic-antimorbidic avidity being a complete explanation of all immunochemical phenomena. Outside the distribution of a few easily recognized bacteria, for example, we have to-day no knowledge whatsoever as to the immediate or final typographical distribution of a single injected morbidic factor of immunological importance. Whether such agents remain in the body fluids, are deposited on cellular-humoral interfaces or are taken up by the living cytoplasm is beyond the reach of current hypothesis. No known facts as to the relation of morbidic factors to humoral, interface and intracellular enzymes, possible hydrolyses, depolymerizations, homologous and heterologous conjugations. Only semi-theological deductions as to the probable length of stay in the human body. A generation of Hektoens, Wellses, Landsteiners and van Slykeses will be required to compensate for this neglect.

VII

In spite of this glaring vacuum in our basic cytological and biochemical knowledge, clinical pressure is so great that a dozen immunologists have hurdled our basic biological ignorance to the tentative working hypothesis that retained biochemically "hybridized" morbidic agents are the protective "antibodies" of the Ehrlich nomenclature, a renaissance of the "obsolete," discredited immunology of Buchner. As a corollary to this hypothesis they have assumed that protective buchnerian "hybrids" can be prepared in the chemical laboratory.

Within the last five years a dozen alleged successful test-tube antibodies have been reported. By incubating mixtures of diphtheria toxin and normal horse serum, for example, Kryshanowski reports the successful test-tube synthesis of a therapeutically active diphtheria antitoxin.[3] By incubating similar mixtures of sera and plant juice Mez,[4] Sasse[5] and Nahmacher[6] report successful artificial specific precipitants for plant proteins and specific agglutinations for plant cells. In their hands these artificial buchnerian hybrids are identical with the natural antibodies following animal inoculation.

Similar successes are reported by the Czechoslovakian clinician Kabelik in his alleged synthesis of specific precipitins for animal proteins.[7] Kabelik, however, is not convinced of the identity of his products with natural precipitins. The Russian urologist Baschkirzev currently alleges successful specific buchnerian bactericides for the gonococcus.[8] It has, of course, long been known that specific agglutinins occasionally appear in artificial bacterial cultures, but their possible buchnerian significance has been overlooked.

Under the assumption that normal antibodies are probably formed as a result of enzyme action, Sdrawosmisslow[9] and Kimmelstiel[10] have incubated mixtures of diphtheria toxin and commercial trypsin, and report the formation of a "diphtheria trypsinate," therapeutically antitoxic. This, however, is not believed by Kimmelstiel to be identical with normal diphtheria antitoxin.

VIII

Of even greater theoretical and clinical significance are Kryshanowski's

[3] *Centralb. f. Bakt.*, 110: 1, 1929.
[4] *Botanisches Archiv.*, 12: 163, 1925.
[5] *Beitrag. Biol. Pflanzen*, 16: 351, 1928.
[6] *Ibid.*, 17: 1, 1929.
[7] *Biologické Listy*, p. 31, 1927.
[8] *Zeitschr. f. Urologie*, 23: 92, 1929.
[9] *Zeitschr. f. Immunitätsf.*, 54: 1, 1927.
[10] *Ibid.*, 62: 245, 1929.

studies of buchnerian hybrids with different serum proteins.[11] While with certain proteins the test-tube hybrids are therapeutically antitoxic, with other serum fractions they are wholly inert. With two serum fractions specific supertoxins are formed, more potent than the original filtrate.

Evidence that similar supertoxins may be formed in the animal body is suggested by Torrey and Kahn's[12] recent report that certain bacterial toxins injected in the femoral bone marrow are locally "hybridized" into highly potent bone-marrow cytotoxins. Absorbed from the local marrow they cause degeneration of all bone marrows of the body, with a resulting, persistent, often fatal anemia, simulating pernicious anemia in man.

IX

Current immunology, therefore, is essentially a revolt against Ehrlich metaphysics, with buchnerian chemistry as the most promising immediate method of attack. The buchnerian renaissance, however, is not repeating former errors. It does not assume that retained biochemically hybridized morbidic agents are the only specific antibodies formed or liberated in the animal body. Nor does the most ardent buchnerian apostle assume that variations in amount and topographical distribution of retained hybrids throw any light whatsoever on the nature of normal bodily defense.

Whatever may be the future of this renaissance immunology, its serious reconsideration at this time throws doubt on many cherished preconceptions of the last three decades. The probability that retained morbidic hybrids may vary qualitatively with time, dosage, portal of entry and topographical distribution of an injected morbidic agent, the possibility that at any one time the retention hybrids may not be identical in different organs, tissues and body fluids, seriously challenges three decades of clinical deductions with suggested vaccines, antisera and diagnostic methods. Proof of the Buchner immunology might necessitate a complete reexamination of forty years of careful and conscientious experimental and clinical work, a threatened research emergency that is officially recognized.[13]

No less disconcerting is the possible bearing of the Buchner theory of biochemical relativity on general biology. Veblen, for example, reports that certain bacteria grown in dilute horse serum are apparently hybridized with horse proteins, as shown by their acquired agglutinability with antihorse precipitins, and their loss of agglutinability with their own specific agglutinins.[14] Veblen's data suggest more radical changes than a mere mechanical formation of horse protein films about the bacteria, as previously postulated by Shibley and others from observed changes in electropotential.[15]

X

The threatened Buchner renaissance marks the beginning of a new era in theoretical and clinical immunology, loss of faith in metaphysical cytology and biochemistry, adoption of the ideals and methods of the older biological sciences. With chastened spirit, but with undaunted hope, with undiminished faith in ultimate clinical victory, for the first time in all history immunology endorses the Hippocratean command, "Draw no deduction from anything except an assured fact."

[11] *Loc. ref.*

[12] *Amer. Jour. Path.*, 5: 117, 1929.

[13] *J. A. M. A.*, 94: 654, 1930.

[14] *Proc. Soc. Exper. Biol. and Med.*, 27: 204, 1929.

[15] *Arch. Path. and Lab. Med.*, 2: 438, 1926.

THE IMPERSONAL OXFORD

By H. P. PERKINS

RHODES SCHOLAR AT OXFORD UNIVERSITY, 1923–26,
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OXFORD is deceptive. Take, for instance, the tourists who have been awed by its moldering masonry. How many of them know that Oxford stone is perhaps the softest that has ever gone into architecture? How many of them know that an Oxford building has to be refaced about once in forty years, so that few of the stones which cause them to catch their breath are older than themselves? Of course Oxford *is* ancient. But the tourist is likely to point with awe to very modern decay. And the educator often assigns a quaint and perhaps pleasing accident as the true cause of Oxford's achievement in civilization.

Talk about Oxford in this country has been based on mistaken conceptions of the great English university. Educators have seized upon superficial features. At the same time a kind of myth has sprung up among college students—a myth in which Oxford plays the rôle of a fairy prince rescuing the student from durance vile.

The educator's view of Oxford has often been developed in a few visits to the high table and the senior common room. There is much delightful talk from the tutors, and answers to questions about pedagogical method are most casual. This tends to nourish the idea that a tutorial is ringed with tobacco smoke and incubates "personal contact." The educator has probably carried this picture with him to Oxford, so that it takes very little of the common room to stamp it in. He is probably familiar with Stephen Leacock's picture of intellectual osmosis in a tutorial: there is no activity in the tutorial except puffing at a pipe, and yet somehow at the end of four years an enormous amount of something valuable has been conveyed to the student. This view has been promulgated so widely that one is tempted to ask why the Pullman smoker has not been accepted as the school for American youth.

I know a college president who has been very zealous in the development of honors work, organized for weekly conferences of student and professor. He still thinks of Oxford in terms of the free and easy palaver of the common room where the dons gather after dinner. This educator often announces to the community which he heads that when students talk so much and so well education will be in our midst. And there is the president of Harvard University, who feels that the division into small colleges is a major factor in Oxford's success. Harvard is on the point of spending thirteen million dollars for houses which will resemble the Oxford college. Dr. Lowell seems to agree with Bagehot that education is largely the impact of youthful mind on youthful mind. We must provide the physical paraphernalia for a friendly rubbing together of a small group of students. This conception of personal contact was naturally not invented at Oxford. With us it is very largely a reaction against the monstrous size of our universities. But the reaction is often caught looking to Oxford for its next step, and it sees the advance in terms of "personal contact."

In the spring of 1924 the Harvard English department decided to adopt the tutorial system. It provided funds for two of its younger instructors to spend the summer in England, doing some research and incidentally picking up some suggestions about tutoring at Oxford and Cambridge. Since these two gentlemen had only the summer at their

disposal they found neither Oxford nor Cambridge in session. The few tutors with whom they conversed told them that there was very little to say about the tutorial. It is as obvious and natural as a meeting of two people who have work to do; one merely follows one's nose to find it. Provide an adequate faculty and an adequate interest on the part of the student and you will always have it.

Is there then nothing to be learned about the machinery of the intellectual life at Oxford? There is, but unfortunately these two very estimable representatives of Harvard were unable to get at it. They were not prepared to understand what lies behind the tutorial and makes it so powerful an instrument. There is a great deal behind its "personal contact." The English tutor does not normally attempt to deal with students whose interest has not been developed before they come to the university. He often regards the American attempt to make the tutorial an instrument for creating interest as a hopeless one, and one which distracts attention from the main problem, which is to build up interests before the student appears in the university. Without such interests already developed the sort of personal contact which one finds in an Oxford tutorial would not exist.

The Oxonians who talked to the representatives of the Harvard English department in 1924 probably listened in some astonishment to the basic ideas which the latter were outlining as the *raison d'être* of the new venture. A tutor at Harvard was to pull the threads of the various courses together and rouse interest by any kind of assignment which seemed to be on a level with the student's capacity. There were to be occasional meetings of groups of eight or ten, with a fire as a center, and all as informal as possible. And it was something of this sort which the Harvard instructors expected to find in the Oxford tutorial. Their ideas were sufficiently remote from the real basis of the tutorial as it is conceived at Oxford to make it rather difficult for an Englishman, even a willing Englishman, to answer their questions in his own sense. It would be difficult for the Englishman to indicate his profound disagreement with the informal, ultra-personal view of education without dilating on the elaborate scheme of organization of which the tutorial is the focus, and for this he rarely gets a hearing.

Naturally the Harvard English department has done a great deal of useful tutoring, since many of its tutors are intelligent. And its conception of tutoring has probably changed somewhat with increased experience. But Harvard has not been able to profit by suggestions from Oxford, because it does not understand them. One would naturally assume that suggestions from Oxford would have to be reinterpreted in the light of the difference between English and American conditions, but even that is not possible, because the difference itself is not understood in this country. In the last few years we have had in the tutorial system at Harvard and the honors courses of institutions like Swarthmore and Williams a departure from the older American methods. But we must constantly keep in mind the fact that these experiments have not brought us any nearer to Oxford, though they make use of certain methods which have a superficial resemblance to Oxford procedure. The principle of English education differs from both the new and the old in American projects.

Oxford's success is due to its assumption that the major part of a university education is to be secured at school. And it does not merely think this (many professors at Harvard and Swarthmore and Wisconsin do that) but it acts upon the assumption. English parents usually make much greater demands of a school than do American parents. Yet

even this is not counted sufficient to guarantee that freshmen will be adequately prepared. Oxford takes special measures. Each of the twenty-one colleges offers a large number of scholarships to be awarded as the result of examinations in a special field like classics or chemistry. The usual value of a scholarship is $350 to $500 per annum; they range up to $1,000, and a few in each college pay smaller sums. These scholarships are sometimes won by men who can afford to pay their own expenses and who therefore give up the emolument to a poorer competitor but retain the title because of the honor it brings with it.

When money is given to an Oxford college it usually takes the form of a scholarship to be awarded on the basis of examinations. It is not given exactly for the support of a deserving boy, but rather for the support of a deserving boy whose intelligence and training have been shown to be such as can profit by further cultivation at Oxford. This is demonstrated largely by written examinations.

A school's reputation from the scholastic point of view depends solely on the number of scholarships at Oxford and Cambridge which it is able to win. Naturally a good deal of attention is paid to sifting out the promising boys and developing them in their best subject. Though Oxford makes less noise about opening its portals to rich and poor alike, it has actually been more efficient than most American institutions in giving the poor boy an education. It assumes that there will be no use in having the poor boy in a university unless he is properly schooled. It has taken the necessary steps to see that the schools develop and train any boy who shows promise. If the school can lay its hands on a bright boy by offering scholarships, or in any other way, it will receive an immediate distinction for what it does to pick him out of the ruck and give him the necessary tools.

The school's anxiety to maintain its reputation by winning scholarships affects a great many more boys than are included among the actual winners of scholarships. Any boy who has a chance to win a scholarship will be given plenty of individual attention, and in his last year or two will probably be released from a good deal of the school routine to read intensively on his own, and write essays for criticism by a master.

"Write essays"—this looks like a program in English which would be of very little use for examinations in classics or chemistry. But the awarding of a scholarship at Oxford in classics or chemistry will always involve an essay to test the candidate's command of English and his capacity for thought. The examination for the scholarship will also call for a display of his mastery of English history and literature.

It would be a mistake to think of the preparation for winning a scholarship as a highly specialized one. Take scholars who have won their emolument in a subject like history. Some of them may elect to do part of the classics program after entering Oxford. They have been well enough prepared at school to keep up with the classics scholar in his special field. The scholarship examination is not designed to favor a narrow training.

This should be kept in mind when it is said that the English *university* student has a greater tendency to specialize than the American student. In a way this is true. He has a better basis for specialization, since he already knows a good deal when he comes to the university.

It should also be remembered that a lot of essay writing has taught him to apply what he knows. The thoroughness of his studies and the amount of independent or extra-classroom activity which is usually included give him a maturity in which the American fresh-

man is notably lacking. A great deal more attention has been paid by the school to developing his interests and finding out what he is best fitted to do. For all these reasons he is more capable of making an intelligent choice of his special field in the university. Interests are developed by hard work under the direction of a man who has every chance to see what the boy is like. This is a fact of which many American schools seem notably ignorant. We have a tendency to regard interest as the gift of a gracious divinity, so that not much hope is entertained of building it up by work. And since we often manage to put off hard work until after college, it frequently happens that our interests are not developed before middle age. Also our schools are overcrowded and have little opportunity for special attention to the promising boy, so that there is not much chance of noticing the germs of interest.

Boys who have been educated very intensively before they come to the university are prepared to do very astonishing things. It should be kept in mind that there are hundreds of these scholarships distributed among the twenty-one colleges at Oxford, and that many who do not hold scholarships were prepared to compete for them. The ordinary classics scholar coming to the university at eighteen or nineteen can run through the thousand odd lines of the Bacchae in a long evening. He reads scads of Demosthenes and Lucretius at sight.

Some educators and a large part of the American public would be repelled by this description of the scholarship system at Oxford because I have put the main emphasis on the extraordinary command of Latin and Greek which it produces. It would have been just as easy to dilate on the vigorous encouragement which is given by the scholarship system to modern history or science. But Oxford is chiefly interested in making sure that the best freshmen have a complete mastery of Greek and Latin. Oxford is even more strongly convinced now than it was a century ago that the highest type of university training, and the only type which does justice to men of real capacity, is an intensive study of the classics.

The reader who wishes to understand this policy must first dismiss his experience of the study of the classics in an American college or university. In the first place, the command of languages makes possible a kind of study which is almost unknown in this country, even among graduate students. A freshman who has gone to a good American prep school and has stood near the top of his class is ready to tackle an assignment of a couple of hundred lines of Ovid. To be told to read through the Metamorphoses in a couple of days or a week would stagger him. Any one of five or six hundred Oxonians could accomplish it. Thus they are in a position to treat the Metamorphoses as literature.

In the second place, the scholarship system has done its best to make sure that they are really saturated in English history and literature. That is something to be accomplished at home and in school, and in casual reading. Acquaintance with problems of the day is often stimulated at the dinner table. Politics is constantly in the foreground. Periodical material on these subjects is large in quantity and high in quality, and it is read. The classics scholar usually knows his own country far better than the student taking a course in "American national problems" knows his. The English undergraduate can afford to travel far afield because he is seeing a good deal at home.

The third reason for dissociating the classics program at Oxford from its American equivalent is that it succeeds in studying a civilization. In studying this civilization it puts its chief emphasis on philosophy. The American

teacher of Greek is nearly always anxious to point out to his students that he knows nothing about philosophy. Even when he is giving a course in the Platonic dialogues he makes a habit of referring to the philosophy department questions about the thought. This may be praiseworthy modesty on his part, but it is none the less a very unfortunate separation, and may lead to a serious misconception of Greek civilization or a serious loss of Greek contributions to present-day thinking. Even if one contended that a civilization could be understood without its philosophy, it would be hard to apply this rule to the Greeks.

The study of the Greek classics is the usual way of beginning philosophy at Oxford, and no one who is teaching philosophy in England has begun the subject in any other way.

American students of philosophy are not very completely saturated in any of the great literatures. This often makes their work barren, and gives it a technical flavor born of unreal problems. The work is remote from the main current of European reflection—Shakespeare, Goethe—and is correspondingly naive and small minded.

Plato was trained in a very different way, as is obvious to any reader of the Republic, with its frequent references to Homer and other poets. The English student is able to approach Plato with nearly the same background. He has been soaked in Plato's own literature. It is not uncommon for him to quote Homer in connection with a paragraph from the Republic, and he seems to do it with taste and aptness. At school and in his first two years at Oxford he becomes thoroughly familiar with Homer, Aeschylus, Sophocles, Lucretius, Vergil, Demosthenes, Cicero and some others from whom a selection can be made. Thus he begins his philosophical studies with a mind which differs very much from that of the usual student of philosophy in this country.

The program of Greats, or *literae humaniores,* which fills the Oxford undergraduate's last two years, has for its *pièces de résistance* Plato's Republic and Aristotle's Nichomachean Ethics. The first assaults are made on these in the long summer vacation, and they are read a number of times. In connection with each one of these books the student writes eight or ten essays. This is precisely half of all his work for a term of eight weeks. It should, therefore, be reckoned as equivalent to one half of our program, or two and one half courses, for eight weeks, or something more than a semester course devoted to each book. This leaves out of account the large amount of time devoted to each of them in the vacations. Normally the student has two essays each week, one in philosophy and one in history. For the latter subject he reads Thucydides and Herodotus, and modern works on Greek and Roman history. There is usually a term (eight essays, something more than a semester course in our terminology) for a book like Bradley's "Ethical Studies," and another term for logic, say again Bradley's. It should be remembered that before each term there comes a vacation (six weeks at Easter and Christmas). It is a time for soaking up what will later be formulated and criticized in the essays of the term itself. Both the logic and ethics studied with Bradley or Croce, and the term's work in modern philosophy from Descartes to Kant, will involve frequent rereadings of Plato and Aristotle, who have dealt perhaps more effectively with the same problems.

The men come back to English life with the framework of a civilization laid bare—and laid bare not by doctrinaire philosophy but by reflection springing out of a thorough saturation in all the relevant material, poetry, history, science. Science? Where does that come in? One of the most amusing delusions of the modern mind is its idea that science was born in the seventeenth

century. As a matter of fact it would not be hard to maintain that the Greek achievements were more important than let us say the English contribution. In order to understand the Athenian thinkers (Plato and Aristotle) who were saturated in Milesian and Sicilian science, the student of Greats becomes moderately familiar with the beginnings of science. While this naturally does not supply him with the knowledge of science which would be desirable in a perfect education, it gives him a far better chance to grasp the main purpose and method of science than is granted to the man who takes "baby physics" in one of our colleges. He also has a better chance to find a place for science in a unified scheme of human activities.

Dr. Meiklejohn in his experimental college at Wisconsin has been giving his freshmen a year with the Greeks. But this is to be sharply distinguished from the program I have just described, since the Wisconsin students have neither the mastery of Greek nor the wide acquaintance with American history, literature and current problems which make the Oxford venture a fruitful one. Nor do they spend a twentieth of the time which the English student gives to the mastering of a few monuments of the Greek genius.

This is a program which all the best students at Oxford are expected to follow, and they display considerable unanimity in electing it.

Many American students would resent being held down for several years to a minute study of Plato and Thucydides. Of course the man who has an interest in history and literature finds that Plato's remarks about artists and his criticism of institutions grow more fruitful the more he reads. When there is a background in the student's mind every return to the Republic means an expanding of the interest in history and literature. This well deserves to be called freedom, but it is not the license which the American student often imagines he will find at Oxford.

Very recently an attempt has been made to build up a modern equivalent for the concentrated survey of Greek and Roman civilization. It is called the school of philosophy, politics and economics. Mŏdern English constitutional development, modern economic theory, the industrial revolution, the philosophy of Immanuel Kant—all these things give a special significance to the years after 1760. It was felt that if taken together they would provide a good view of the modern world. Unfortunately the philosophy tends to carry one back into the seventeenth century while the politics and economics move forward into the nineteenth. English philosophy in the nineteenth century is not nearly so fruitful or fascinating as that of the period which culminates in Hume (1750), and yet it is the natural accompaniment for the industrial revolution and parliamentary development. What is even worse, the literary background (which would make the program as solid and concrete as the equivalent study of the ancient world) is so enormous that it takes years to acquire it. The scholarship system which encourages saturation in English history and literature has done comparatively little to produce the same command of French and German masterpieces. The languages which would be essential are perhaps even worse taught than they are in the United States. There are scholarships in modern history and modern languages, but the holders of them have not usually read any modern philosophy at school, whereas the classics scholar has always read some Plato before he comes to Oxford. Thus in the modern field there is a separation of language, literature and philosophy in marked contrast to the union which is maintained between these elements for the student of the ancient world. Ordinary history is well taught at school, but the constitutional develop-

ment and the economic theory is passed over lightly, while as I have already pointed out there is no modern philosophy at school. Thus the whole preparation for this modern curriculum is far below what we find with the classics scholar.

The new program has been very popular with foreign students. Since it was started they have been able to work in philosophy without knowing Greek. Then there are always a number of Englishmen who have completed their four years of classics and now take a year to read some modern economics, brush up their history and really come to grips with Kant. It might almost be said that such a five-year program has become the rule with first-rate men. They also get a chance to polish up a modern language hastily learned at school, and to start on a new one. Considering the popularity of Italian philosophy and their command of Latin it is not surprising that this new language is usually Italian. The speed with which this modern curriculum is mastered by the classics student provides good testimony both as to his general training and his equipment in modern subjects.

There has been a good deal of talk in this country about the Oxford student's freedom from lectures. This is almost entirely a myth. The Oxonian attends about as many lectures as his American counterpart, or if he fails to go he is likely to hear about it at the end of the term when he is called up alone before the assembled dons of the college. This should be contrasted with the effort which has been made at Swarthmore to free honors students from lectures. Now of course many people at Swarthmore are perfectly aware that this is not Oxonian, and in any case Swarthmore is not pretending to imitate Oxford. But many Americans seem to believe that it is an Oxford idea. President Lowell is one of them. His reports often allege a contrast between Harvard adherence to lectures and Oxford neglect of them.

It should be remembered that the Oxonian is a good deal more highly developed intellectually than his American counterpart, and hence is capable of digesting a larger number of lectures in a given time. Moreover he rarely attends a lecture unless the book which is being commented upon in the lecture has been studied or at least read over with some care in the vacation. Usually he is devoting a good deal of time to the preparation of essays on the book at the same time that he is hearing lectures about it. He therefore goes to the lecture with a good many questions that he wants answered. At the same time he has the material organized to a point which makes it unnecessary for the lecturer to attempt to cover everything.

There is some freedom involved in the fact that no "homework" need be done for these classes. All the writing is done for tutors, of whom there are normally two (one for philosophy, the other for history), so that two essays, or occasionally three, must be turned out every week. That is all the work there is to do. The usual time for the preparation of an essay will vary from four to twenty hours. Thus some time is often left for reading which is more casual or bears less directly on the problem in hand. And the student has time to do the essay in any way which appeals to him. Only he must remember that a searching fire will be directed at irrelevance. If he wants to go far afield he must justify his point of view to the tutor. Anything he can bring to bear will be welcomed if he really does succeed in making it apply. There is elasticity here, where the mere assignment would prognosticate only a rehash of Plato. It is elasticity made possible by hard work in other fields and brought into connection with the Republic. And it is controlled by high standards as to what is and is not relevant.

Even the assignments themselves can be varied if the student will suggest a topic which fits into the general field the tutor has chosen for the work of the term. This subject could be changed only by shifting over to some honors school other than Greats (*e.g.*, English, history). Normally the tutor will run through a series of essay subjects, most of them old standbys. The relation of each term's work to the next is similarly guided by the Greats tradition, modified by the practice of the college and the tutor's preferences. The whole is related to an examination which will cover all the work.

Taking it by and large this is a mill which must be gone through, must be accepted for better or worse. This is not by any means a new thing for the undergraduate. In school he was early obliged to make certain choices in studies, and after that was put through a coherent routine. If he was picked out to be pointed for a scholarship he was released from some classwork and more attention paid to his special capacities, but the body of work to be done was considerably increased, while higher standards of coherence and relevancy were applied to its organization. He probably had very little to do with the making of the actual decisions as to what he would study, though efforts were made to consider what was likely to bring out his talents most effectively. In the same way he was probably put through a routine of games by all kinds of direct and indirect pressure. He was beaten by older schoolmates and masters if he broke any of the rules. There were a large number of conventions to which he had to conform. This is not altogether admirable, but it breeds a kind of ruthlessness about private impulses, a disregard for the merely comfortable in human relationships, which is quite exhilarating.

Every hour's discussion with the tutor presents a chance for elasticity in the treatment of prescribed subjects. But here too the student is not allowed to be formless. It is taken for granted that people who expect to talk must take some trouble to inform themselves about the subject. In the eyes of the tutor the Oxford student is often slack, but to the American teacher he would probably seem a marvel of intellectual curiosity. The Oxford tutorial is the only institution which approaches an editorial office in the severity of its criticism of bad writing, and it is just as hard on loose talking. English tutors visiting honors groups in this country often impress the American student as brutal. When they see an opening they swing from the canvas.

And the unreality of academic discussion is hateful to them. They give vigorous condemnation to the student's failure to drag his own opinion out into the open and give it an overhauling. He must not discuss issues which are remote for him. A good many sorts of academic pretense yield before the insistent effort to say what one really thinks, and then base the discussion on the issue so raised. This gives the talk a directness which is rude but refreshing. And those who emphasize the informality of the procedure and its closeness of personal contact are undoubtedly right in doing so. Only it is sometimes not noticed that the directness is strictly intellectual, that the informality is informality in brushing aside irrelevancies. The personal contact is a purely intellectual affair. The tutor's concern for private welfare and his friendliness in connection with the business of daily life disappear as soon as the grindstone of discussion has been brought forward. Behind this concentration on the problem lies a rigorous training for both tutor and student. Even the directness and informality of the tutorial are strictly conditioned by this training. It takes some practice to

put one's intellectual cards on the table, to put aside academic pretense. To the uneducated freshman who usually presents himself in our colleges it comes as rather a rude shock to be asked, "Do you really believe this stuff you've been quoting from the book I assigned you?"

This is very closely bound up with the brutal directness of Oxford college life. There is plenty of snobbishness, though it is not always in the ascendant at most colleges. Little effort is wasted trying to remain on friendly terms with those who do not meet with one's immediate approval, and no effort at all is made to conceal what one thinks of them. The play "Journey's End" represents a group of English public-school men in the trenches. The commanding officer has been drinking heavily and is approached on the morning after by the orderly.

"Like a plate of sardines, sir?"

"I should loathe it!"

It would be hard to find anything more typical of the English undergraduate's manner of expression. Americans have doubtless had the same feelings. They have doubtless refused the sardines, and even with harsh words. But there is something in the intonation and the idiom "I should loathe it!" of which few Americans would be capable.

In the last term before the comprehensive examination most of the meetings with the tutor are devoted to the answering of old examination papers. This puts a special emphasis on practice in bringing knowledge to bear on specific questions, and in this last period criticism of form and phrasing is brought into the foreground. There have been a good many examinations before the final test is reached, perhaps an average of one a term. But these serve simply as exercises in relevant writing, and as guides to future assignments. They are marked by the tutor concerned, who thus has another opportunity to bear down on looseness and unreality. They have absolutely no bearing on the degree or the class ranking secured from the university.

The comprehensive examination covering the whole of the work is an important feature of the routine, but it has received rather more than its due share of attention on this side of the Atlantic. Doubtless it is important to demand that the work shall not be crammed, and the comprehensive examination is a good way to make sure that this demand is met. But it is even more important to have a unified program which does away with cramming because it does away with fragmentary work. The elective system in this country has played havoc with unified programs, and it does not do much good to introduce comprehensive examinations until the elective system has been given up. It is not much use indulging in diatribes against cramming unless we root out the piecemeal idea of education which makes cramming practically inevitable. Piecemeal education is still in the ascendant, for instance, at Harvard. Swarthmore seems to have a clearer idea of what is meant by coherent work, but many of the programs are so crowded that the result is not much different from what one finds at Harvard. Neither at Swarthmore, Harvard nor at any other American institution of which I know has it done a great deal of good to introduce the comprehensive examination.

ELECTRICAL EFFECTS REVEALED IN STARLIGHT

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ONE of the most fruitful and fascinating methods of modern astrophysical research is the application of new principles originating in pure physics to the study of the stars. It was in this manner that the father of astrophysics, Sir William Huggins, made his most notable discoveries. In the year 1859 Gustav Kirchhoff communicated to the Berlin Academy of Sciences a paper in which he demonstrated that a mass of glowing gas radiating light of certain definite colors, or wave-lengths, would absorb just these same wave-lengths, and no others, when placed between the spectroscope and a luminous body emitting a continuous spectrum of all colors. The emission lines were observed to give place to absorption lines, which appeared against the background of the continuous spectrum.

At the time when this new physical principle became known to the world, Huggins was already at work in his own little astronomical observatory at Tulse Hill, in the south of London. He immediately seized the opportunities offered by Kirchhoff's announcement and used the new knowledge for an interpretation of his spectroscopic observations. And "so it was with every new advance, in whatever field. Sir William read of it at once, discussed it with Lady Huggins, called it to the attention of his correspondents, and carefully examined into its bearings on astrophysics."[1]

In 1870 Huggins installed in his laboratory a large magnet for the purpose of studying the effects of magnetic force upon the spectral lines of various elements. In this he failed because his instruments did not give sufficient optical resolution, and it remained for Professor Zeeman, of Holland, to show (in 1896) that when a source of light, for example a radiating gas, lies within a magnetic field, its spectral lines are split up into a number of components. The complete theory of the Zeeman effect is one of the most difficult branches of modern physics, but a brief qualitative explanation may here be given.

According to the quantum theory light is produced by minute negatively charged particles, called electrons. Under normal conditions the electrons revolve in fixed orbits around a central particle, or nucleus, which is charged with positive electricity. The combination of a nucleus with one or more electrons revolving around it forms an atom of a chemical element, and may in many respects be likened to the solar system: the nucleus corresponds to the sun and the electrons take the places of the various planets in their orbits. An undisturbed atom, it is believed, neither produces nor absorbs light. But if a small, though definite, amount of energy is supplied to it, for instance in the form of heat waves, certain electrons jump from one orbit to another. Every time an electron jumps from a larger orbit to a smaller one, a certain small amount of monochromatic light, called a quantum, is emitted. A sufficient number of these quanta, when observed through the spectroscope, appear as a line of definite color.

Now, it is well known that the force exercised by a magnet must affect any material particles near it that are

[1] G. E. Hale, *Astrophysical Journal*, 37: 149, 1913.

charged with electricity. Consequently it seems perfectly natural that in the presence of a magnetic force the electrons will move around their nuclei in slightly "perturbed" orbits, that the size of their jumps will be altered and that the line originally appearing in the spectrum will be shifted to a different shade of color. The mathematical theory of perturbed electronic orbits predicts the appearance in the spectrum of several closely spaced lines in place of the original line. This group of components is the Zeeman pattern. Its character and degree of resolution depend upon the nature of the chemical element and upon the intensity of the magnetic force.

Zeeman's discovery proved to be of great importance to astrophysics. Nearly twelve years later Professor George Ellery Hale observed that certain absorption lines of the sun's spectrum, which usually appeared sharp and narrow, changed into a pattern identical with that of the Zeeman effect when the telescope was turned directly on a sunspot. This led him to conclude that sunspots are huge magnets and that the intensity of their magnetic force could be measured from the degree of resolution of the spectral lines.

The existence of magnetic effects in light naturally raised the question as to whether there might not be similar effects due to electric charges. In 1913 Professor J. Stark found that an electric charge placed close to the radiating atoms of certain luminous gases would change the spectral lines in structure and sometimes in position. The theoretical reason for this effect is somewhat similar to that for the Zeeman effect. The electrons are perturbed in their orbits under the direct influence of the electric charge, and the light-quanta are changed in wave-length, resulting, as before, in a color shift. Stark and other investigators have found that all chemical elements are subject to such electrical changes, but the resulting spectral patterns are not always the same. Certain elements, for example hydrogen and helium, are affected by comparatively small electrical charges, while other elements, for example iron, are affected only by very strong fields. Furthermore, it has been found that certain lines split up into a number of components, while others are merely shifted in wave-length. The electrical disturbances make themselves apparent in a large variety of ways, and considerable work remains to be done in the laboratory before we shall know all about them.

Even a weak electrical charge, such as can be collected on a rod of hard rubber by rubbing it with a piece of fur, could produce a change in the wave-length of light, but in actual practice rather strong sources of electricity are needed in order to produce measurable displacements in the spectral lines. Consider, for example, the hydrogen line beta, which is one of the strongest absorption lines in the blue region of the sun's spectrum. In a strong electric field this line splits up into a large number of polarized components, symmetrically spaced on both sides of the original position of the undisturbed line. Two of these components are particularly strong and these alone appear in a spectroscope of small resolving power (Fig. 1). If the field corresponds to one unit on the centimeter-gram-second-electrostatic system, the wave-lengths of the outermost components will differ from the wave-length of the original line by about six one hundredths of an Ångström unit. On a photograph obtained with the spectrograph of the Yerkes Observatory this would amount to a displacement of about six one thousandths of a millimeter. In order to understand the amount of electricity in one unit on the centimeter-gram-second-electrostatic system imagine two metallic balls, each one gram in weight, one of which is station-

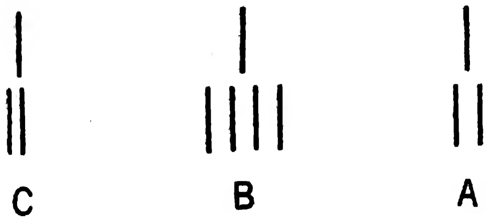


FIG. 1. THREE TYPICAL STARK PATTERNS

AS SEEN IN A SPECTROSCOPE OF MODERATE RESOLVING POWER. THE NORMAL UNDISTURBED LINE IS SHOWN AT THE TOP, AND THE PATTERNS BENEATH THEM. (A) HYDROGEN-BETA LINE; (B) HYDROGEN-GAMMA LINE; (C) HELIUM LINE 4472, SHOWING "FORBIDDEN" COMPONENT AT WAVE-LENGTH 4470.

ary while the other is suspended on a string about one meter in length. If both balls are charged with the same amount of positive electricity the stationary ball will repel the suspended ball. The greater the charge of electricity the stronger will be the repulsion. If the charge is such that the suspended ball is repelled to a distance of one centimeter from the stationary ball, the quantity of electricity in each ball is said to be one unit on the above-mentioned system. One such unit working at a distance of one centimeter would produce a splitting of the hydrogen line corresponding to a displacement of about six one hundredths of an Ångström unit, in both directions from the center. For stronger electric charges the displacements become greater, and as an approximation it is usually sufficient to assume that the line-displacement is proportional to the intensity of the electric field. A doubling of the charge produces a doubling of the line-shift.

In practice we do not always use the unit of electricity defined above. The field intensity is often expressed in volts per centimeter. One volt per centimeter corresponds to one three hundredth part of the electrostatic unit, and the conversion from one system to another is performed by simply dividing or multiplying by 300. For example, in the case of the hydrogen beta line a field of 100,000 volts per centimeter will shift the outermost component to a distance of approximately twenty Ångström units from the original wave-length.

If a star were a charged sphere, comparable to a charged ball of metal in the laboratory, it should produce a Stark pattern in the absorption lines of its spectrum. Astronomers have looked for such patterns but have found none. The most extensive and by far the most accurate investigation of this nature was undertaken some fourteen years ago by Dr. Hale and Dr. Babcock at the Mount Wilson Observatory. They concluded that the electric field strength at the level where the lines of the sun's spectrum originate is less than 200 volts per centimeter. Accordingly, if the gaseous sphere constituting the sun's bulk is charged at all, it can contain only a comparatively small amount of electricity. The same is true of all stars thus far investigated.

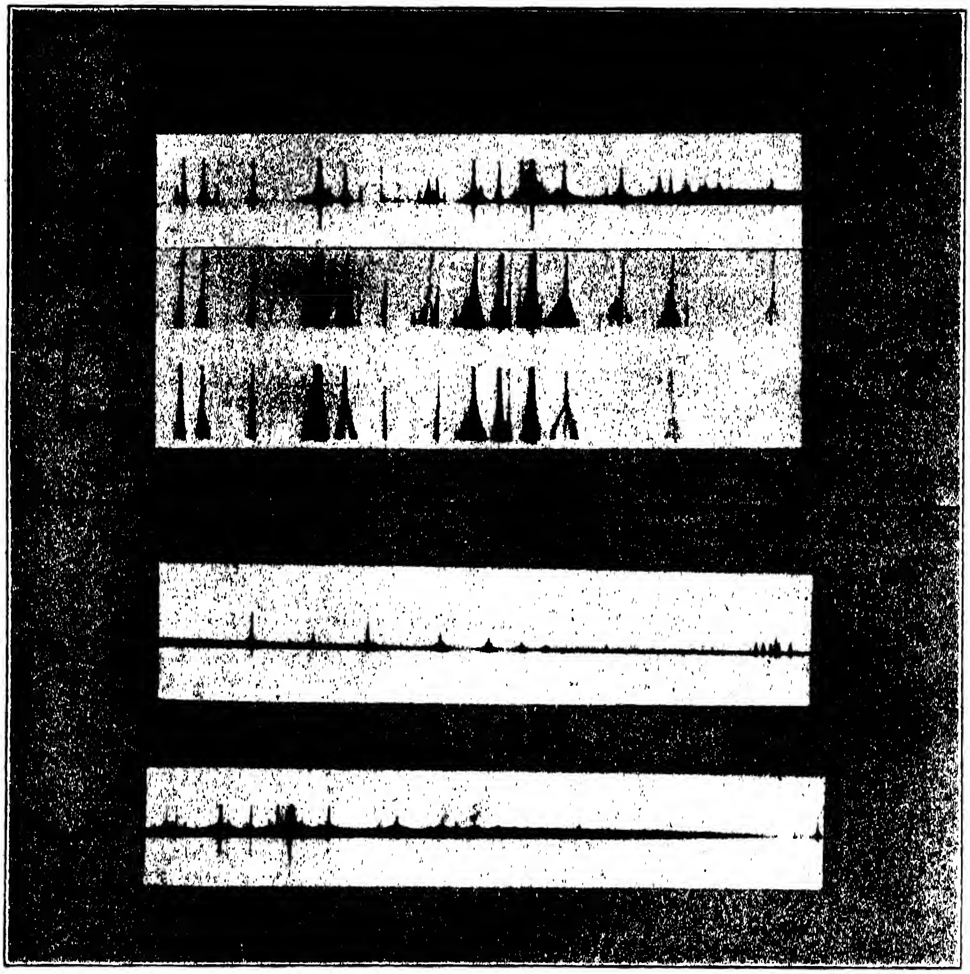
The absence of a real Stark pattern in the spectral lines of a star does not necessarily mean that no effects of electrical forces are present. The star may not be like a charged ball of metal brought into close contact with a source of light, perturbing the electronic jumps. Laboratory experiments have shown that electrical effects may be observed in luminous gases in which there are no visible sources of electric force. As a matter of fact, a gas itself contains a sufficient amount of electricity to produce perturbations in the electronic jumps. Under ordinary conditions the positive charge of the nucleus of any given atom is firmly bound to one or more electrons, the whole forming a neutral atom. However, if a gas is "energized," as when it is heated to a high temperature or exposed to ultraviolet radiation, some of its atoms may

lose one or more electrons. The process involved is called ionization.

Under the influence of energy coming from the outside certain atoms in the gas may be forced to throw off one or more of their electrons. These electrons dash off with velocities depending upon the amount of energy swallowed by the atom. If an atom swallows a very small amount of energy, the electron may not be loosened sufficiently from its bonds to escape completely. The atom becomes temporarily excited, but it soon returns to its original state and throws out its excess energy in form of light. If the amount of energy swallowed by the atom is just sufficient to loosen the electron, the latter will leave the atom, but will not be supplied with energy in the form of motion. It will remain stationary and will finally be caught by some other atom that may also have lost one electron in the past and will thus be eager to capture any stray electrons in its path in order to complete its electronic family. If the energy from the outside is very great, the excess over what is needed to loosen the electron from the parent atom is bestowed upon the electron in the form of motion. Such an electron will move with great speed through the gas until it happens to hit another atom and becomes a captive once more.

In the atmospheres of the stars the gases are known to be highly ionized. From a study of their spectral lines we find that most atoms have lost at least one electron and many have lost two, three or even more of them. All these free electrons are moving about in the gas. Each is charged with a minute quantity of negative electricity, equal to 0.0000000005 electrostatic unit. As we have already seen, an ordinary atom is electrically neutral. In order to be so, it must contain an amount of positive electricity just equal to the sum of all the negative charges collected on the electrons. As soon as one electron is knocked off the atom, the remaining part, the ion, has an excess of positive electricity left over, and consequently there will be in the gas not only negative charges moving about, but also an equal quantity of positive charges collected on the ions.

Now suppose that in its flight through the atmosphere of a star such a charged particle—ion or electron—happens to pass very near to a hydrogen atom that is about to radiate the hydrogen beta line. What will happen? Naturally the electric charge will cause perturbations in the electronic orbits of the radiating atom and the emitted line should display the characteristic features of the Stark effect. It is true that the charge of a single electron is extremely small, so small, indeed, that it may not at once be clear how it could possibly produce a measurable resolution of the spectral line. But the disadvantage of possessing so small a charge is offset by the fact that an electron can approach a radiating atom much more closely than could a visible source of electricity. We have seen before that a charge equal to one unit on the electrostatic system, placed at a distance of one centimeter from the radiating gas, will displace the outermost components of the hydrogen beta line by an amount equal to about 0.06 of an Ångström unit. This is a small displacement; we should consider a charge at least ten times as large, say ten units, in order to produce a resolution that would be readily discernible. The charge of an electron is 20,000,000,000 times smaller than this quantity. The question is, of course, how closely the electron approaches the radiating atom. At a distance of one centimeter the resolution would be practically zero; but in a gas there are really no limitations for the approach between electron and atom other than their respective sizes. The size of the electron



—*From the Astrophysical Journal.*

FIGS. 2 TO 4. THE STARK EFFECT IN HELIUM

AS PHOTOGRAPHED IN THE LABORATORY BY DR. TARO SUGA AND DR. Y. FUJIOKA, OF TOKYO, JAPAN. FIG. 2 REPRESENTS THE STARK EFFECT IN THE BLUE AND VIOLET REGIONS; (a) SHOWS THE MOLECULAR ELECTRIC BROADENING OF THE LINES, DUE TO THE PRESENCE OF CHARGED ELECTRONS AND IONS. THE LABORATORY CONDITIONS WERE MADE TO REPRESENT AS NEARLY AS POSSIBLE THE CONDITIONS INSIDE THE ATMOSPHERE OF A VERY HOT STAR; (b) SHOWS THE STARK EFFECT PRODUCED BY A CONSTANT ELECTRIC FIELD. MANY LINES ARE SPLIT UP INTO COMPONENTS. FIGS. 3 AND 4 SHOW THE STARK BROADENING OF SPECTRAL LINES IN THE ULTRA-VIOLET PART OF THE SPECTRUM.

is so small that it can be neglected; that of an atom varies according to the species considered, but in general it may be assumed to be not larger than 0.00000001 centimeter. Consequently an electron can approach an atom to a distance of one half this amount, or 0.000000005 centimeter. The electric force which, when exerted upon the atom by the electron, causes the perturbations in the electronic jumps, varies inversely as the square of the distance. While the

charge is 20,000,000,000 times less than that of our visible charge of ten units, the total value of the force would prove to be much greater; it would equal $\frac{(200{,}000{,}000)^2}{20{,}000{,}000{,}000}$, or approximately 2,000,000. The resolution produced by an electron at its minimum possible distance turns out to be two million times greater than that produced by a visible charge of ten units at a distance of one centimeter.

However, the motions of atoms, ions and electrons in a gas are distributed at random. Consequently only a very small proportion of the free charged particles will approach the radiating atoms to the nearest possible distance of 0.000000005 centimeter. The majority will fly past the atoms at somewhat greater distances, depending chiefly upon the degree of pressure applied to the gas. In a compressed gas the particles—atoms, electrons and ions—are so closely packed together that the average distances between them are small. On the other hand, if the gas pressure is low, the distances are correspondingly larger, and the observed effects upon spectral lines should be smaller. In the case of a stellar atmosphere the average pressure may be estimated from the work of Russell,

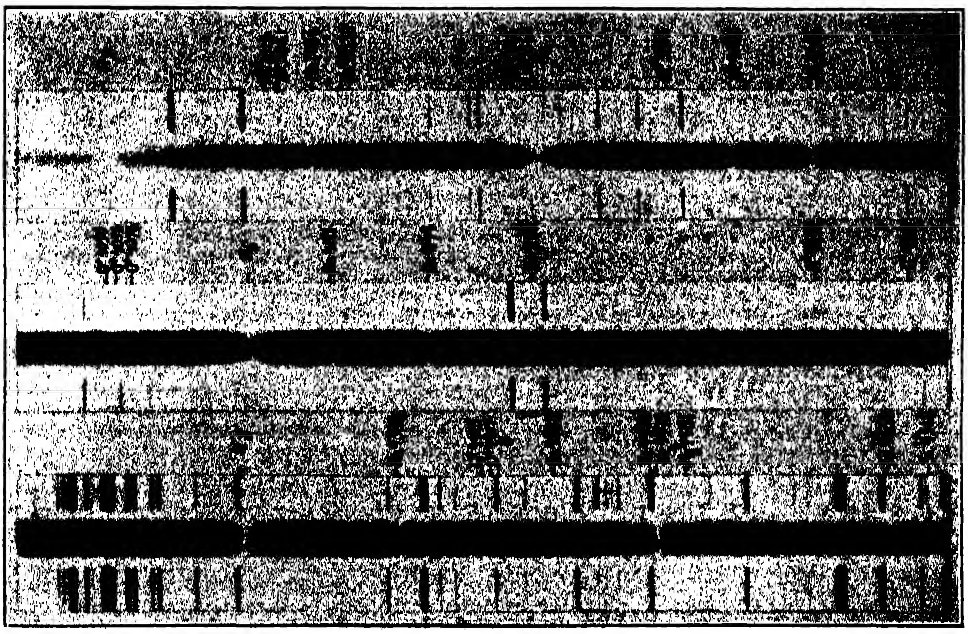


FIG. 5. SPECTRUM OF THE STAR 88 GAMMA PEGASI

AS PHOTOGRAPHED WITH THE BRUCE SPECTROGRAPH OF THE YERKES OBSERVATORY ON JULY 17, 1929, AT 7^h08^m UNIVERSAL TIME. THE THREE STRIPS REPRESENT VARIOUS PORTIONS OF THE SPECTRUM. THE BLACK BAND IN THE MIDDLE OF EACH IS THE CONTINUOUS SPECTRUM OF THE STAR. THE STELLAR ABSORPTION LINES (WHITE IN THE PHOTOGRAPH) CROSS THE CONTINUOUS SPECTRUM. THE BLACK LINES AT THE TOP AND BOTTOM OF EACH STRIP ARE DUE TO THE TERRESTRIAL COMPARISON SPECTRA OF IRON AND TITANIUM. NOTICE THE GREAT WIDTH OF THE HYDROGEN LINES $H\gamma$, $H\delta$, $H\epsilon$ AND $H\zeta$. NOTICE ALSO THE GREAT WIDTHS OF THE HELIUM LINES 3926, 4009 AND 4026 AS CONTRASTED WITH THE SHARPNESS OF THE HELIUM LINE 3965. THIS IS IN AGREEMENT WITH THE REQUIREMENTS OF THE STARK EFFECT. THE LINES OF THE HEAVIER ELEMENTS ARE ALL SHARP AND NARROW, *e.g.*, Mg 4481, Si 4553, ETC.

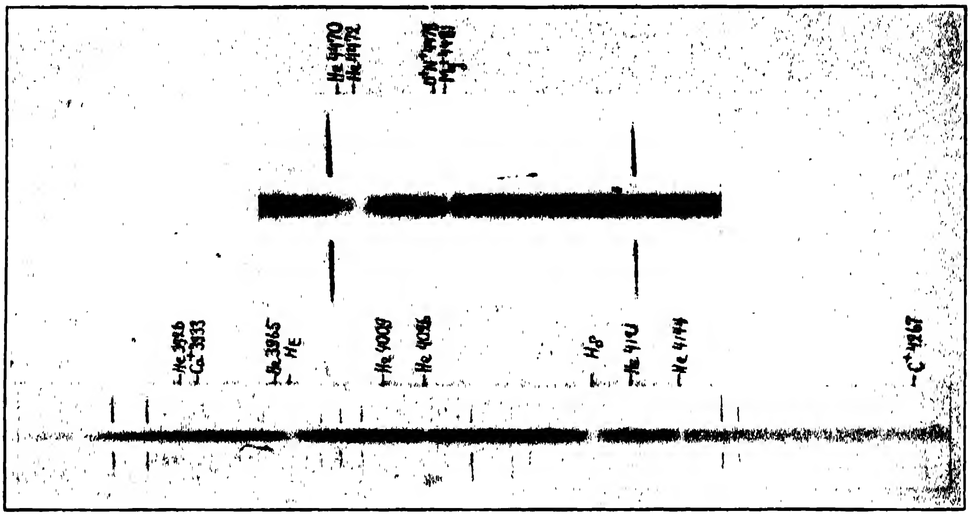


FIG. 6. SPECTROGRAMS OF TWO STARS

AT THE TOP IS A HIGH-DISPERSION SPECTROGRAM OF THE STAR 88 GAMMA PEGASI, OBTAINED AT THE YERKES OBSERVATORY ON SEPTEMBER 21, 1929, AT 4^h38^m UNIVERSAL TIME. THE "FORBIDDEN" HELIUM LINE AT WAVE-LENGTH 4470 IS SHOWN TO THE LEFT OF THE STRONG PERMITTED HELIUM LINE 4472. NOTICE ALSO THAT THE TWO HELIUM LINES—PERMITTED AND FORBIDDEN—ARE APPRECIABLY BROADER THAN THE MAGNESIUM LINE 4481 OR THE LINE AT 4478 WHICH IS A BLEND OF IONIZED OXYGEN AND IONIZED NITROGEN.* THE "FORBIDDEN" LINE CAN NOT BE PRODUCED IN THE HELIUM SPECTRUM EXCEPT IN THE PRESENCE OF ELECTRIC FIELDS. THE WIDENING OF THE HELIUM LINES IS IN AGREEMENT WITH THE STARK EFFECT. AT THE BOTTOM IS A SPECTROGRAM OF THE STAR 85 IOTA HERCULIS PHOTOGRAPHED ON JULY 3, 1929, AT 7^h11^m UNIVERSAL TIME. THE HYDROGEN LINES ARE VERY WIDE, DUE TO STARK BROADENING.

* Since the above was written, this line has been identified by the writer as due to doubly ionized aluminum, wave-length 4479.89.

Milne and others. Professor Russell and Professor Stewart, of Princeton, have computed the average distance to which charged particles will approach a radiating atom in a stellar atmosphere and have found that the effect upon spectral lines, such as those of hydrogen, should be well within the accuracy of measurement.

Let us now consider the observational side of the matter. If we were dealing with one single radiating atom and one charged particle, the observed result would be a splitting up of the spectral line into the ordinary Stark pattern. But in reality we are not observing a single atom. The light coming to us from a star is the integrated effect of an enormous number of separate atomic acts. A moderately strong line in a stellar spectrum is produced by the combined action of something like 10^{42} absorbing atoms. Every individual atom is subject to perturbations produced by the nearest charged particles. But while in some cases these particles may happen to be very near, producing a wide resolution of the line, other atoms may be rather far away from any electrons or ions and will give rise to narrow Stark patterns. The combined effect is, then, a composite picture due to the superposition of 10^{42} individual Stark patterns of all possible resolutions, resulting in a broad and hazy line in which the individual patterns can not be recognized.

Assuming our conception of the star's atmosphere with its free electrons and charged ions to be correct, we should expect to find broad and ill-defined absorption lines for such elements as are known to be susceptible to Stark effect. This is what is actually observed. The hydrogen lines are always broad. In many stars they reach a width of 100 Ångström units, sometimes even more. Somewhat lesser widths have been recorded for the helium lines. Both elements are known to be susceptible to Stark effect and their widening in stellar spectra is in excellent accord with our expectations.

Until recently, however, there was no proof that the observed broadening was not produced by some process other than Stark effect. To interpret the vast mass of facts that a photograph of a star's spectrum presents is by no means simple. Broad lines can be due to a great variety of causes, and some of these were actually known to be present. It was therefore necessary to eliminate all known factors affecting the width of a spectral line and to find whether there remained a broadening that could be attributed definitely to Stark effect. The molecular Stark effect demands very definite forms for every given line, and it was necessary to determine whether the behavior of the stellar lines was actually in conformity with these theoretical requirements.

The most essential of these demands are the following.

(1) The amount of broadening caused by molecular Stark effect should be roughly proportional to the degree of resolution observed in the laboratory. A line that shows a large separation in a weak field should appear more broadened than a line that is less susceptible to electrical perturbations.

(2) In many cases the ordinary Stark effect is not symmetrical. In fact, the perfectly symmetrical pattern is characteristic only for hydrogen. All other elements show more or less asymmetry in their Stark resolution. Corresponding to this asymmetry we should expect an unsymmetrical broadening of certain lines in the stars.

(3) Under the stimulus of the electric field new spectral lines make their appearance. Such lines are "forbidden" under normal conditions, and their appearance in any spectrum is a good indication of the presence of electric fields.

(4) The Stark effect is most pronounced for elements of low atomic number. The heavier elements are only slightly susceptible to electrical perturbations. Hydrogen shows the greatest resolution; helium follows next; then come the other light elements. In the stars, then, we should expect, primarily, hydrogen and helium, and possibly nitrogen and oxygen, to exhibit the broadening effect. The other light elements are either absent in the stars or show such weak lines that no accurate measures can be made of them.

(5) The lines of any given element are not equally affected by electric fields. In helium, for example, there are lines that are almost as susceptible to Stark effect as the hydrogen lines, while others remain almost unaffected, even in the presence of very strong fields.

(6) Within any given spectral series (a group of related lines in the spectrum of a single element) the Stark effect is weakest for the lines situated farthest toward the red end of the spectrum and increases toward the violet and ultraviolet.

These several characteristics were tested[2] for the helium and hydrogen lines in the spectra of many stars. All were found to be present. Those helium and hydrogen lines which are subject to Stark broadening invariably appear

[2] *Astrophysical Journal*, 69: 173, 1929; 70: 85, 1929.

fuzzy and wide, even though the heavier elements, such as magnesium or silicon, show perfectly sharp and narrow lines. The observed broadening increases toward the violet as we proceed along any given series. Many helium lines are observed to be unsymmetrically broadened—in excellent agreement with the laboratory patterns of the Stark effect. But of greater significance than any of these is the identification of the "forbidden" helium lines with a number of previously unidentified stellar absorption lines. Thus we find the evidence overwhelmingly in favor of the existence of molecular electric fields in stellar atmospheres.

An advance of scientific knowledge in one direction frequently leads to new developments in other directions. A study of the hydrogen and helium lines in many stars disclosed the fact that the intensity of the Stark effect is not the same for all stars. As we have seen, the resolution of the lines in the individual Stark patterns depends upon the distance between atom and charged particle, and this distance, in turn, depends upon the average gas pressure in the stellar atmosphere. Unless this is the same in all stars the average distance between atom and charged particle will not be the same. Hence the observed broadening of the line would serve as an index of the pressure. Such a relationship has been derived mathematically and tested by observation; by means of accurate measurements of stellar spectrograms the exact value of the pressure, and hence of the density, may be determined.

The atmospheric density is a very important characteristic of every star; it is closely related to the volume. A so-called "giant" star has a large volume, and consequently the gravitational attraction at its surface is small. Such a star has an atmosphere of low density and shows little, if any, Stark effect. On the other hand, a "dwarf," though nearly as massive as a giant, has all its mass concentrated into little space, and the gravitational pull at its surface is strong; it has a dense atmosphere and displays a strong Stark effect.

Much remains to be done before we shall be able to form a complete picture of the molecular electric phenomena in the spectra of the stars. Possibly certain lines of nitrogen and oxygen may also be found useful in determining the intensity of the Stark effect. But the laboratory data relating to these elements are still incomplete, and their astrophysical interpretation is therefore difficult.

So far as we can tell at present, the average molecular field in a stellar atmosphere is of the order of 1,000 to 10,000 volts per centimeter. Such a field would not be considered strong from the laboratory point of view, where fields of several hundred thousand volts per centimeter are produced. The average pressure would be something like 10,000 times less than that of air at the surface of the earth, a condition resembling, in the ordinary sense, a "vacuum" rather than an atmosphere.

THE PROGRESS OF SCIENCE

PROFESSOR DEMPSTER AND THE AMERICAN ASSOCIATION PRIZE

THE seventh award of the American Association prize of $1,000 was made at Des Moines to Dr. A. J. Dempster, professor of physics in the University of Chicago. This prize is awarded annually to the author of a notable contribution to the advancement of science presented at the annual meeting. The funds for the prize are generously supplied by a member who does not wish his name made public. The committee on award was this year composed of the following members: Charles E. Allen, University of Wisconsin, *chairman;* P. W. Bridgman, Harvard University; Fay-Cooper Cole, University of Chicago; S. C. Lind, University of Minnesota; H. L. Rietz, University of Iowa.

Dr. Dempster's contribution constitutes an important extension of the work of the French physicist, Louis de Broglie, for which the Nobel prize in physics was recently awarded. Dr. Arthur H. Compton has said that "the most important contribution of twentieth century physics is that the physical world can be reduced to three kinds of particles, protons, electrons and photons, and that each of these particles has also the characteristics of waves. The last stage of this work is the proof that protons, the positively charged parts of matter, have wave characteristics. It is this completion of the great work of twentieth century physics which has been accomplished by Professor Dempster."

According to Professor Henry G.

PROFESSOR A. J. DEMPSTER AT WORK IN HIS LABORATORY

Gale, president of the American Physical Society, "physicists, seeking to explain the ultimate nature of things, had believed that light was simply a wave form, and that atoms, which consist of negative electrons revolving around a positive nucleus, or proton, were simply particles. Professor Compton in 1926 proved that light is not only a wave but also a stream of particles, or photons, bundles of radiant energy. In 1927 two investigators at the Bell Laboratories, Davisson and Germer, revealed that the negative electrons are not only particles but that each particle also acts as a wave. The final evidence in the cycle has now been adduced by Dr. Dempster, who has proved that the positive protons have also wave-form as well as particle-form. These three discoveries are probably the most striking advances in physics in recent years."

Professor Dempster, during the last eight months of experimentation, succeeded in taking photographs of the positively charged hydrogen nuclei in a manner which proved them to be vibrating approximately 1,000,000 times as fast as ordinary light. By shooting the protons through a crystal in a vacuum, he was able to show pattern marks on the sensitized plate. If the proton had been merely a particle without vibration, nothing but a dot would have been revealed on the photographic plate.

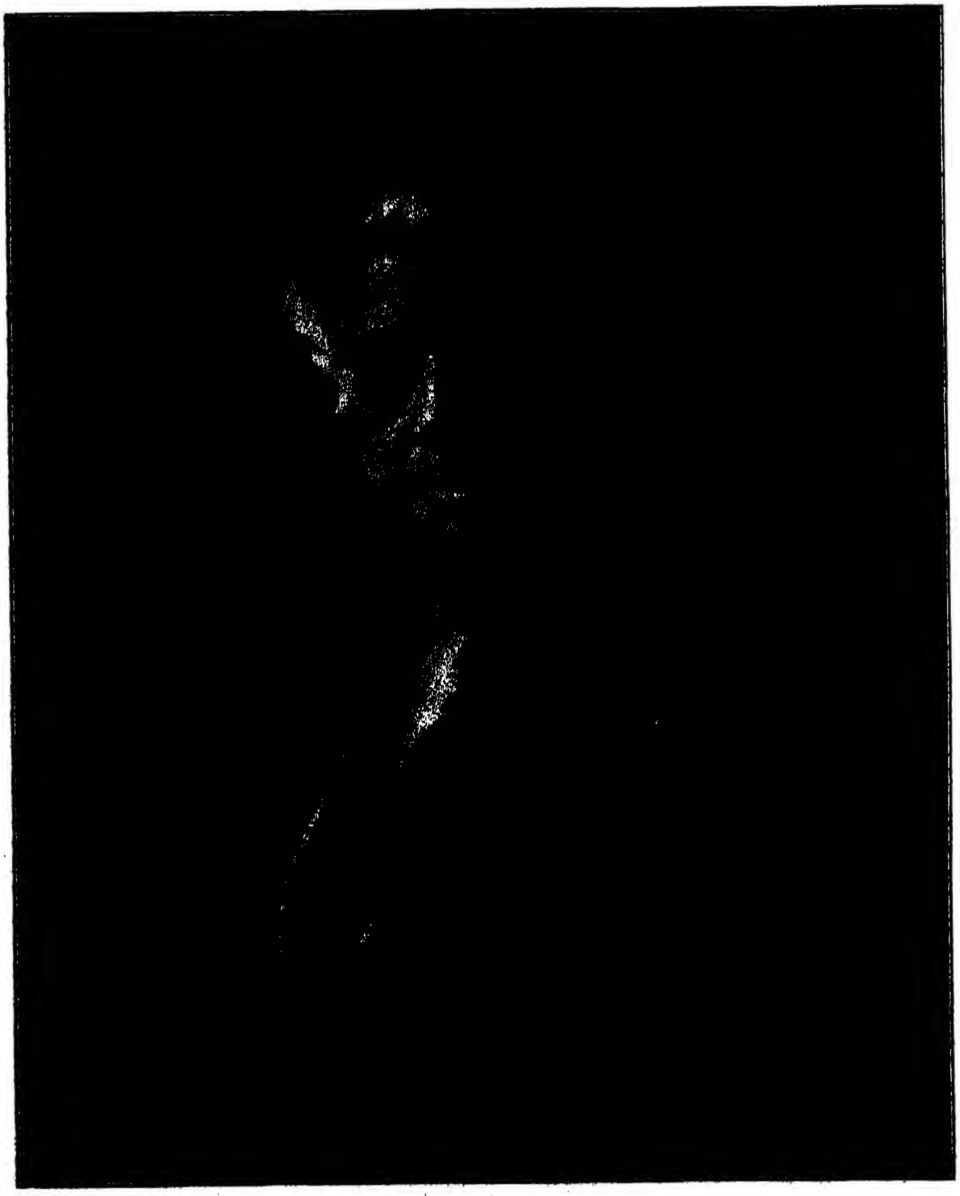
This "diffraction pattern" was explained by Professor Dempster as being similar to the diffused appearance of sunlight through an umbrella, a phenomenon peculiar to things having a wave-form. "In these experiments a calcite crystal takes the place of the umbrella, and is used as a mesh to control the particles. The hydrogen protons in these experiments penetrated the crystal in much the same way that light photons would, and their patterns on the photographic plate leave no doubt as to their wave-properties. The experiments completed have so far been confined to hydrogen. But since all the elements consist of the same thing or things, in different arrangement, it can be assumed that the protons of all substances would act in the same manner. Hydrogen is the simplest of the elements. We are now applying the method to helium, the next simplest. How protons, electrons and photons can be both waves and particles at the same time is perhaps the greatest problem now confronting physicists. This experiment does not throw direct light upon that obscure relationship but helps to clarify the problem."

Dr. Dempster, who is forty-three years old, has been a member of the physics department of the University of Chicago for fifteen years. He is a graduate of the University of Toronto and of the University of Chicago, and has studied at Göttingen, Munich and Wurzburg.

THE TOTAL ECLIPSE OF THE SUN IN CALIFORNIA

The first total eclipse of the sun for 1930 will occur on April 28 across a narrow strip of California about half a mile wide. In answer to a request by the University of California that the army air service cooperate with Lick Observatory in observations of this eclipse, President W. W. Campbell has received word from the U. S. army headquarters in San Francisco that the requisite type of plane is available and that such cooperation will be gladly offered.

Tentative plans call for the services of one plane at an altitude of not less than 10,000 feet, over Napa Valley, between Napa and St. Helena, and perhaps of



Christine Ladd-Franklin

LECTURER ON PSYCHOLOGY AND LOGIC AT COLUMBIA UNIVERSITY, DISTINGUISHED FOR HER CONTRIBUTIONS TO THESE SUBJECTS, WHO DIED IN NEW YORK ON MARCH 5, AGED EIGHTY-TWO YEARS.

another plane equipped to take moving pictures of the eclipse shadow and of the eclipse itself.

In explanation of the cooperative plan, President Campbell says:

The purpose of the airplane plan is to carry the observer well above the highest clouds which might be in the way of eclipse observers located on the earth's surface. The total phase of the solar eclipse will last not more than one or two seconds. The shadow of the moon on the earth's surface will be not more than one half or five eighths of a mile in width, and for an observer to locate his observing station where the shadow of the moon in its rapid northeastern travel will pass directly over him and give him the second or two of totality will be difficult, and it is quite likely that the slight uncertainties in our knowledge of the precise position of the moon will leave many intending observers a little too far north or a little too far south to have the shadow pass over them.

The sky will not be very dark at the instant of totality because the moon will succeed in just a little more than covering the sun's image. I should guess that the observers who are fortunate enough to find themselves for a second or two in the shadow of the moon could read fine newspaper print about as easily in the open air as they would a minute or two before sunset on a clear day. This estimate, however, is very uncertain, but there will be no difficulty whatever in reading ordinary newspaper print at the time and place of totality.

The university is now preparing an observing station to photograph the eclipse from the earth's surface near Camptonville, Yuba County. This expedition, which will be under the charge of Dr. J. H. Moore and Dr. D. H. Menzel, is financed by William H. Crocker, of San Francisco, chairman of the regents of the university.

The plane to be used for high altitude observations will be of the open-cockpit type, of such construction that the upper wing will not interfere with the view of the observer or of the pilot. For a few moments before and after the eclipse, the plane will fly in the direction in which the shadow moves, northeastward, in order to increase by a little period the length of time that the total eclipse may be viewed.

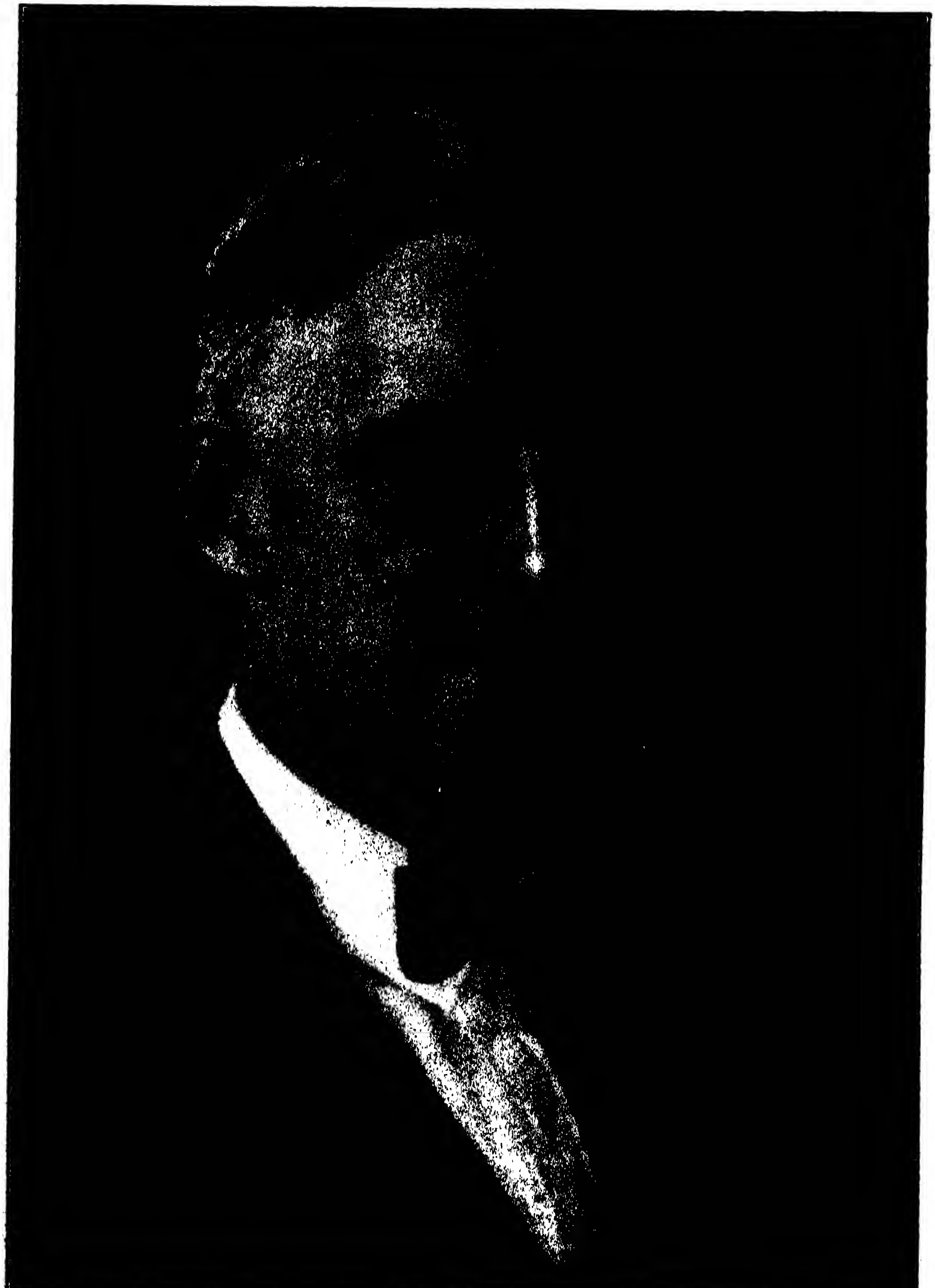
It is suggested that there might be some interest in the taking of moving pictures of the eclipse, as also of the shadow on the ground, providing that it has edges sharp enough.

Concerning the accuracy of the predictions of the path of the eclipse, Professor Ernest W. Brown writes in *Science:*

The brief duration and the narrow path of totality of this eclipse, visible in California, make the question of the accuracy of the predictions of some interest to observers. Perhaps a brief statement of the problem, free from technical terms, may be of value.

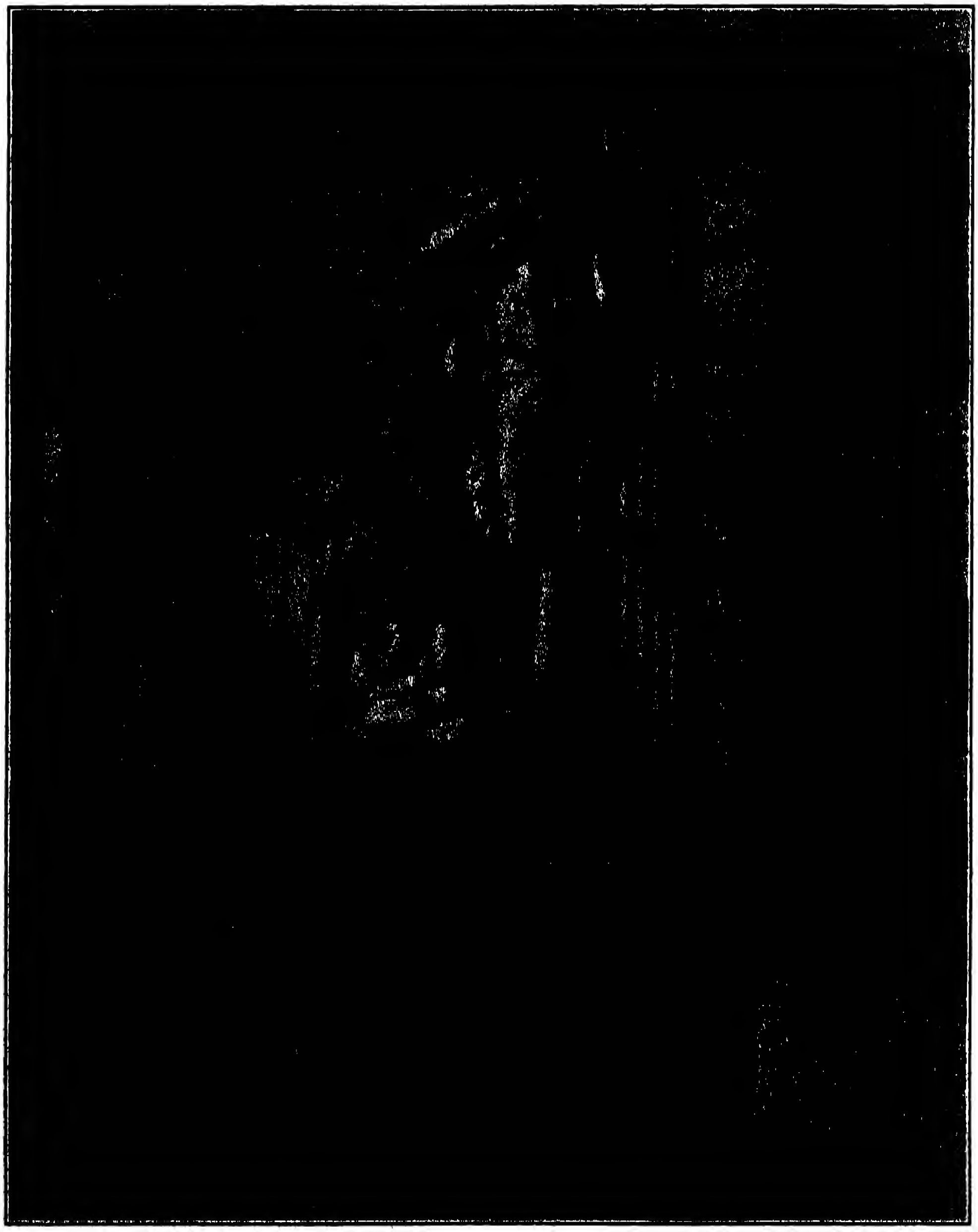
The errors of the prediction arise mainly from two sources, namely, those due to lack of full knowledge of the motions of the earth, moon and sun and those due to the topography of the moon's limb. Owing to a variety of causes, the former have been much diminished during the past six years. There is still some uncertainty due to the changing rate of rotation of the earth, but this affects the position of the path less than it does the time at which totality occurs. In the coming eclipse the position is of importance because a small error may cause the observer to miss totality altogether. In a discussion just published in No. 934 of the *Astronomical Journal*, Dr. D. Brouwer has used all the latest available information, and we estimate that the uncertainty, due to these causes, of the position of the path given by him in a direction perpendicular to the path is less than a quarter of a mile.

The uncertainty due to the topography of the moon's limb is larger than this. We have plenty of evidence of valleys on the limb a mile or more deep and of mountains even higher than this amount, but our knowledge of their exact position at the time of the eclipse is not sufficient to enable us to use it for prediction. A valley a mile deep at either of the positions where the grazing edges of the sun and moon give the limits of totality on the earth may alter the edge of the path on the earth by a like amount. In the present case, where the predicted width of the path is considerably less than a mile, it may result in a complete absence of totality anywhere. Professional observers are aware of these facts, and have made up their programs accordingly. Certain classes of observation can be usefully undertaken with these conditions in view.



PAUL ADIN LEWIS

FORMERLY ASSOCIATE MEMBER IN THE DEPARTMENT OF ANIMAL PATHOLOGY AT THE ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH, IN WHOSE DEATH AMERICAN MEDICINE LOSES A LEADER. DR. LEWIS DIED OF YELLOW FEVER IN BAHIA, BRAZIL, WHILE INVESTIGATING THE CAUSE OF THE DISEASE.



—*Photograph from the New York State Museum*

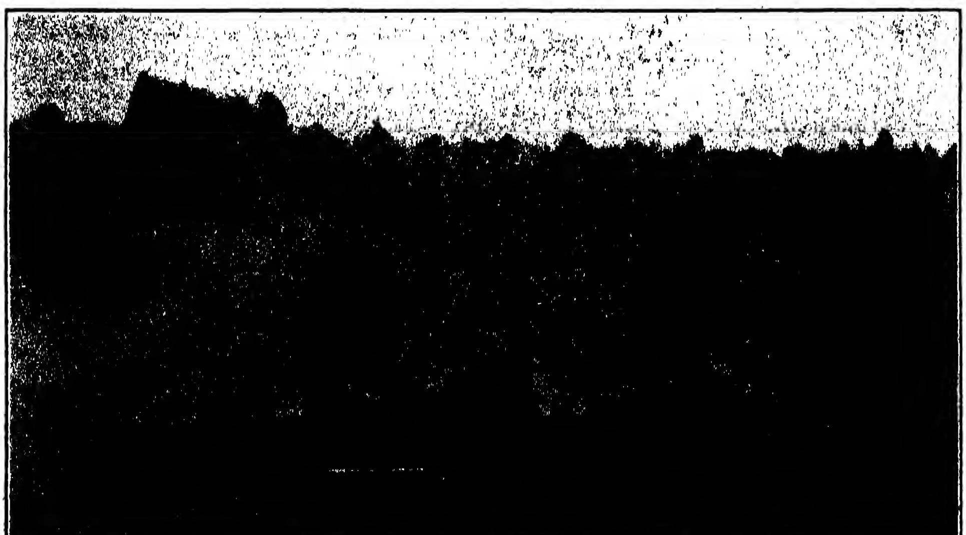
THE JOSEPH HENRY MONUMENT

Recently unveiled in Albany. In the background is the Albany Academy where Joseph Henry made his important discoveries in electromagnetism. In 1846 he was elected as the first secretary and director of the Smithsonian Institution in Washington, and its organization was largely due to him.

THE MARION OCEANOGRAPHIC EXPEDITION

From information given to us by the U. S. Coast Guard we learn of the *Marion* Expedition. Under the command of Lieutenant Commander Edward H. Smith, it sailed into the far north to investigate the currents, ice, weather and other conditions in the furtherance of a knowledge of oceanographic and physical conditions of that vast, sparsely explored water area between the North American continent and Greenland. The expedition cruised 8,100 miles, covering with an oceanographic survey a 450,000 square mile area. A total of 190 observation stations were occupied at carefully selected positions in these waters, and about 1,900 observations of the temperature and salinity of the water were made. The temperature and water samples were taken at various levels from the surface down to near the bottom, use being made of Negretti and Zambra reversing thermometers and Greene-Bigelow water bottles clamped on steel wire cables with over three miles of the wire suspended from the ship. A special bottom-sampling tool was used at many of the stations to obtain good-sized samples of the muds and oozes from the ocean floor. In all 2,000 salinity tests were made on board with the salinometers. These instruments, the only ones of their kind, determine the salinity by means of measuring electrical conductivity of sea water after it has been placed in a special glass cell and brought to a very carefully regulated temperature of 25° Centigrade by a water bath. This instrument was developed by Dr. F. Wenner, of the Bureau of Standards, Washington, D. C., in response to an appeal of the International Ice Patrol service for a quick and accurate method of determining the salinity of sea water and one adaptable to the arduous conditions met on shipboard. Lieutenant Commander Edward H. Smith has been identified with the Ice Patrol service since 1920; from 1922 to 1927 he was the oceanographer of the Ice Patrol and is an authority on icebergs and ice problems of the North Atlantic.

Backed by the indorsement of Coast



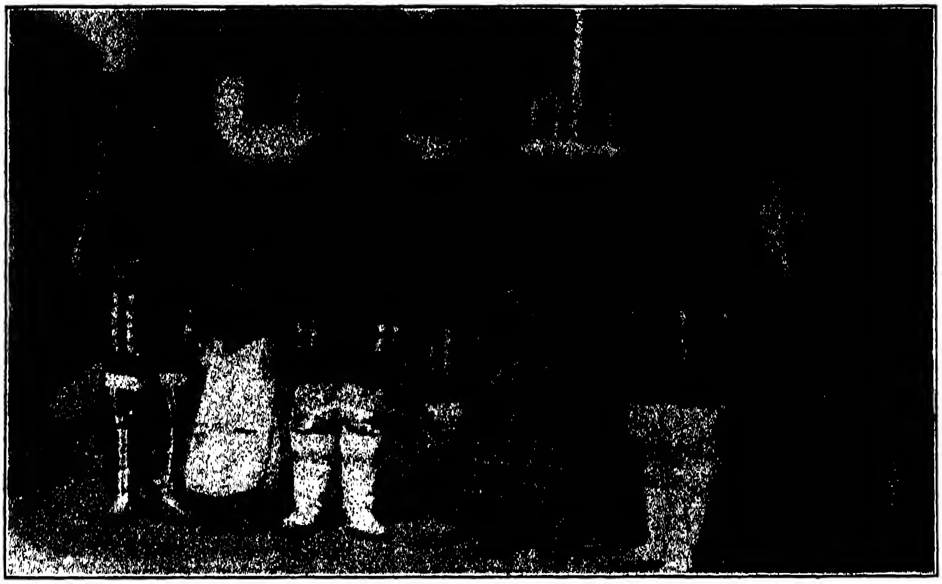
THE CUTTER *MARION* AT THE BASE OF THE GLACIER AT PORT DE QUERVAIN

Guard officials, Commander Smith has in the past few years adapted the so-called Bjerknes formulas of free motion to tracing movements of the dangerous icebergs that every spring infest the waters off the Grand Banks. This work under the direction of the U. S. Coast Guard does much to insure the safety of the transatlantic liners and eliminates the probabilities of another *Titanic* disaster. Few of the general public realize that the ocean areas off Newfoundland are being mapped as to currents every two weeks during the Ice Patrol season and that the various tongues of the Labrador current and the Gulf Stream swirling menacing icebergs into the paths of commerce are plotted like the isobars on a weather map by the Weather Bureau. The Ice Patrol ships, *Tampa* and *Modoc*, each night and morning issue by radio to all approaching ships their ice warnings and forecasts. The current and ice maps constructed immediately on board the ice ships for dissemination to North Atlantic navigators represent a great practical application of oceanography and

—*U. S. Coast Guard*

MAKING OCEANOGRAPHIC MEASUREMENTS ON THE INTERNATIONAL ICE PATROL

THE MAN ON THE LEFT IS LOOKING TO SEE IF THE REVERSING THERMOMETERS IN THE GREENE-BIGELOW WATER BOTTLES ARE PROPERLY ADJUSTED. HE WILL NEXT CLAMP THE BOTTLE TO THE SOUNDING WIRE WHERE IT HANGS OVER THE SIDE FROM THE SHEAR LEGS AND SIGNAL TO THE MAN AT THE WINCH TO LOWER AWAY. THE WIRE WILL BE STOPPED WHEN THE MOTOR WHEEL SHOWS THE BOTTLE HAS REACHED THE PROPER LEVEL, WHERE SAMPLES ARE TAKEN OF THE SEA WATER FOR ANALYSIS.



—U. S. Coast Guard

NATIVE GREENLANDERS AT GODTHAAB, GREENLAND

are a fine tribute to the U. S. government administration of this important international safety work.

Since the famous *Challenger* Expedition, undertaken by the British from 1872 to 1876, many governments and quite a few private individuals and institutions have carried out scientific oceanographic investigations. The U. S. Coast and Geodetic Survey and the U. S. navy have both been identified with notable work along oceanographic lines. A famous pioneer in the physical geography of the oceans was an American naval officer, Lieutenant Matthew Fontaine Maury, and so in sending out the *Marion* our government has in a sense embarked again on a field of exploration in which we have a fine heritage. Practically no oceanographic

ROPING A POLAR BEAR FOR THE NATIONAL ZOO IN WASHINGTON

research work by any one has as yet been done in the area covered by the *Marion*.

It is a little early to draw many final conclusions from the data obtained. However, such great progress has been made with the working up of the observations on account of the short cuts and latest methods that some of the main conclusions and facts brought out by the survey can now be made:

(1) There exists a surface layer five degrees warmer than normal and one hundred meters in thickness covering an ocean area of 100,000 square miles. This additional heat reservoir of tremendous proportions is bound to have far-reaching climatic effects. This supports the assertions of many that Arctic climate has undergone recent temporary amelioration.

(2) Bottom water was found in the trough between Greenland and Labrador, the temperature of which was 2.6° C., having a salinity of 34.90. The observations showed that this water was not produced on the surface or by ice melting, as suggested in the theories of Nansen and Pettersson, but indications point to a slow bottom creep as the source of such water, possibly off the coast of Greenland.

(3) The coastal shelves of Greenland are much narrower than shown on present-day maps, while the Labrador shelf reveals itself to be wider.

(4) Three headlands sighted by the *Marion* north of sixty degrees latitude indicate discrepancies in location of the Baffin Land coast-line on the maps in some cases by as much as twenty miles.

(5) Arctic waters were extremely open. About one thousand bergs in Disko Bay near the glacier front and two hundred bergs stranded on Labrador Coast near Cape Harrison was practically the only ice present at the time of the cruise. The Arctic pack itself shrank back twenty miles off Cape Dier, Baffin Land.

The work next in importance to the determination of the set and drift of the currents and their extent was the sounding out of the sea areas covered. The Submarine Signal Company's fathometer was used for the measuring of the depths. This instrument obtains depths rapidly and accurately by timing the echoes from the sea bottom of sound waves that are sent out from the hull of the ship. It was in use day and night throughout the cruise. The result is that there are recorded over 2,100 carefully taken and located soundings from which the conclusions relative to the bathymetrical contours have been drawn. In addition to the station and sounding work, continuous records of surface temperatures and salinities were kept. All ice and other noteworthy things along the route were recorded by being drawn in on the plotting sheets.

THE SCIENTIFIC MONTHLY

MAY, 1930

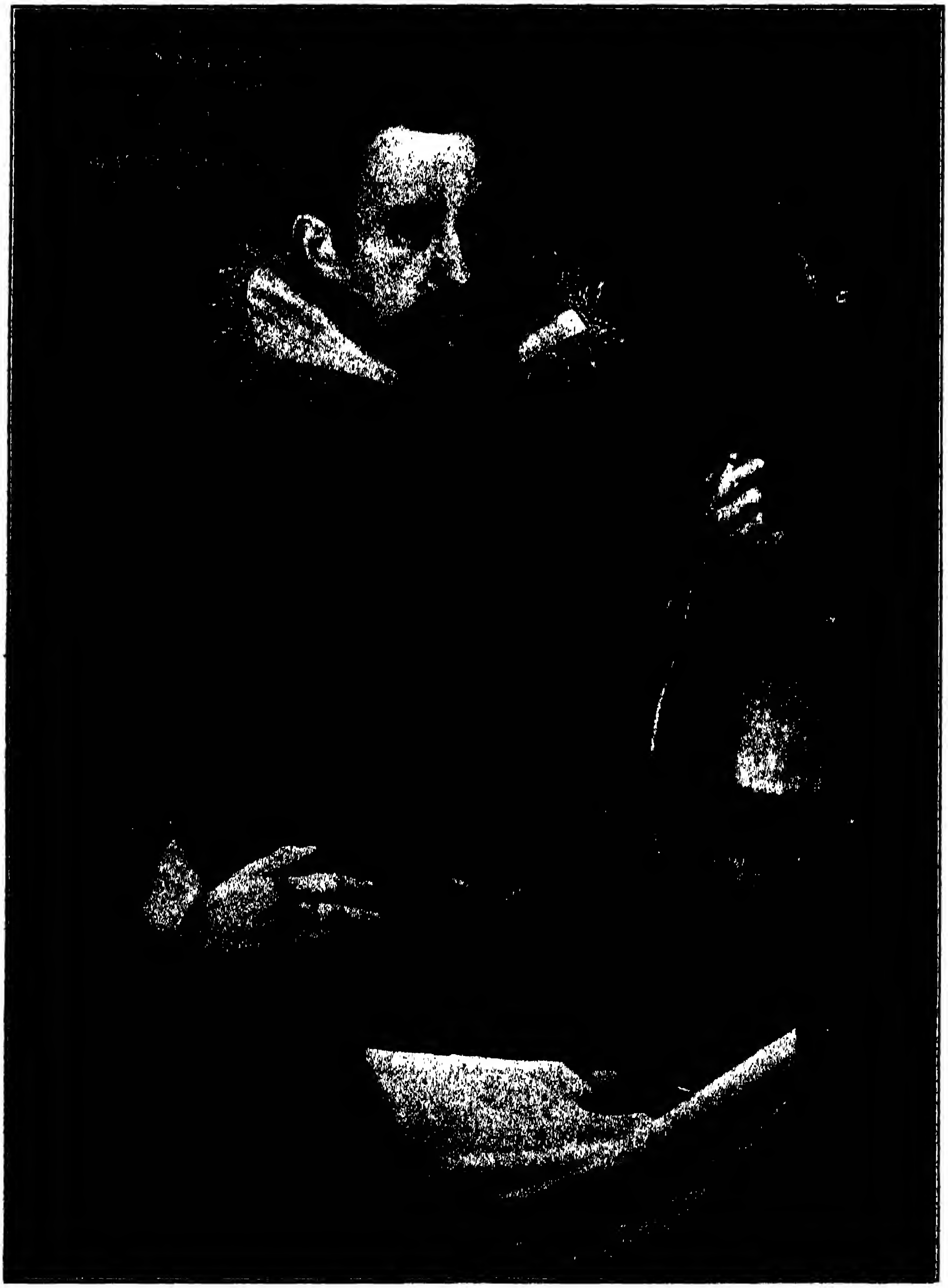
JOHANNES KEPLER, 1571-1630

By Professor FLORIAN CAJORI
UNIVERSITY OF CALIFORNIA

JOHANNES KEPLER was the mystic champion of inductive research. At the age of twenty-five he published a book permeated with mysticism and creative imagination, which took the reading public by storm. The poet Byron was able to say of himself, after the publication of "Childe Harold," "I awoke one morning and found myself famous." No scientist, save Kepler alone, can lay claim to a similar experience. His "Mysterium cosmographicum" (World Secret) was given a reception with which his later and truly great discoveries of laws of planetary motion pale in comparison. About half a century earlier, in 1543, Copernicus had given to the world his "De revolutionibus orbium coelestium" (On the revolutions of celestial spheres). Great as this was, it did not reveal the "secret" of the distances of the planets from the sun. That secret was to be sought in some hidden relation of these distances to geometric figures. Pythagorean mysticism had long ago established a one-to-one correspondence between the regular solid in solid geometry and the elements of Greek chemistry. In such a correspondence the early Greek mind found great satisfaction. Kepler as a youth of twenty-three set about to discover some connection between planetary distances and geometry. Modern realism can not conceive of any causal relation between planetary distances and lines or circles—such, for example, as the dimensions of ladies' skirts or the heights of sky-scrapers in New York City. The belief in such things constitutes mysticism. It is mysticism as surely as is the delusive opinion that the destinies of man are affected by the aspects and the positions of the stars. Modern scientists disbelieve in astrology because no cause in celestial configuration can be conceived to affect the fortunes of a human individual.

At first Kepler dealt with geometrical figures in a plane—lines representing trigonometric sines in a quadrant. Failing to find the desired correspondence, he drew, successively, chords in a circle (Fig. 1) which would form triangles. These equal chords would envelop a smaller circle. He drew also equal shorter chords, yielding quadrilaterals or pentagons, etc. Comparing the radius of the circle enveloped by chords forming triangles with the radii of circles enveloped by quadrilaterals, hexagons, etc., he hoped to find ratios between these circular radii that would equal the ratios of planetary distances. An entire summer was devoted to this search, but without success. We see here the inductive method applied to attempts to discover mystical relations.

Considering the number of sides, there were innumerable different polygons, but there were only six planets then known. This disharmony disturbed Kepler. Finally it occurred to him to pass from two dimensions to three. In solid geometry there were five regular solids—no



JOHANNES KEPLER

AD LECTOREM.

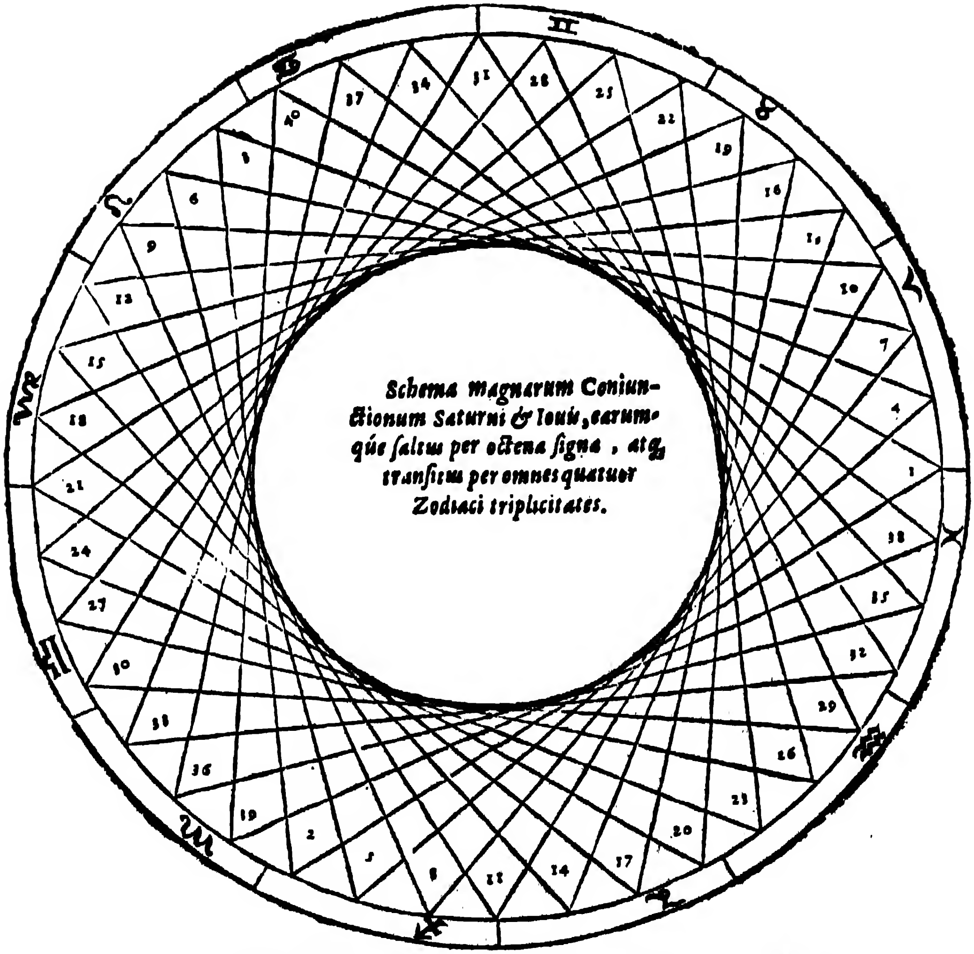


FIG. 1. SUCCESSIVE EQUAL CHORDS DRAWN IN A CIRCLE

THREE OF THEM NEARLY COMPLETING THE CIRCLE AND SATISFYING CERTAIN CONDITIONS RELATING TO THE CONJUNCTIONS OF JUPITER AND SATURN. THESE EQUAL CHORDS ENVELOP A SMALLER CIRCLE. KEPLER FOUND THE RADIUS OF THIS CIRCLE TO BE TO THE RADIUS OF THE LARGER CIRCLE PRETTY NEARLY AS THE DISTANCE OF JUPITER FROM THE SUN IS TO THE DISTANCE OF SATURN.

more, no less. Five regular solids, six planets! Between the six planets there were five spaces. Why not place the five regular solids in these spaces? After many trials and much thought, he inserted between Mercury, Venus, the Earth, Mars, Jupiter and Saturn, respectively, the octahedron, icosahedron, dodecahedron, tetrahedron and cube so that a planetary sphere, lying between two polyhedra, was circumscribed about the inner polyhedron and inscribed in the outer polyhedron. Thus the sphere containing the orbit of Venus was circumscribed about the octahedron and inscribed in the icosahedron. Similarly for the other planets. Here was a compact succession of spheres and polyhedra, in the order shown in Fig. 2. The innermost figure was the sphere containing

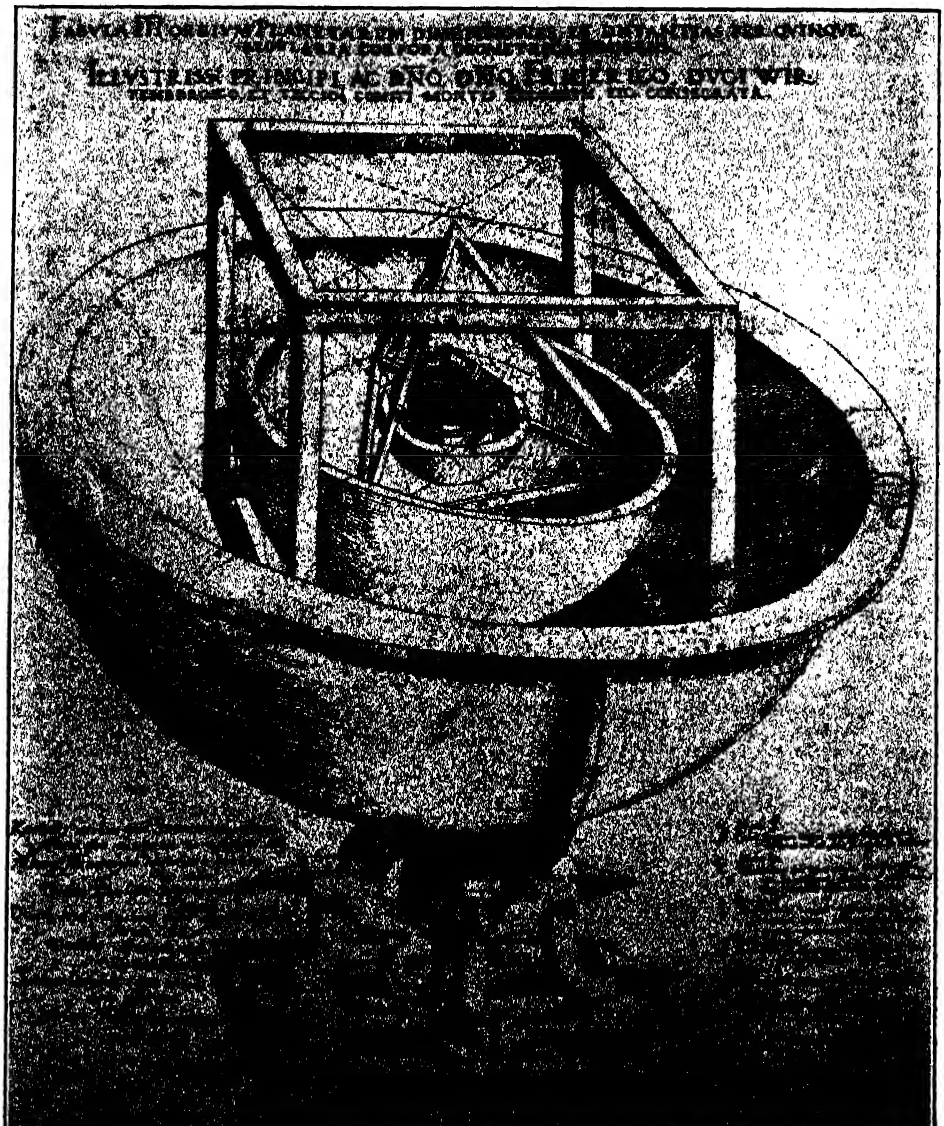


FIG. 2. KEPLER'S COMBINATION OF SPHERES AND REGULAR SOLIDS

THE SPHERES BEING GIVEN SUITABLE THICKNESS. THIS COMBINATION REVEALED TO KEPLER THE SECRET OF PLANETARY DISTANCES. (FOR THIS AND THE OTHER FIGURES IN THIS ARTICLE, ALL TAKEN FROM THE ORIGINAL EDITIONS OF KEPLER, I AM INDEBTED TO THE COURTESY OF PROFESSOR HERBERT M. EVANS, OF THE UNIVERSITY OF CALIFORNIA. HE SUPPLIED ALSO THE PICTURE OF KEPLER.)

the orbit of Mercury; the outermost was the sphere containing the orbit of Saturn and circumscribing a cube. Exercising his mathematical genius, Kepler computed the radii of these spheres. Are these radii to each other as the planetary distances? The hoped-for relation did not exist. Another great disappointment! But wait, had all facts been taken into consideration? No.

Copernicus and the Greeks had known that a planetary orbit is not one simple circle. Like the Greeks, Copernicus obtained a closer approximation to the observed facts by the aid of other circles, called "epicycles." For each planet he constructed a fairly complicated system of them. Thus he required four epicycles for the moon, three for the earth, seven for Mercury and five each for Venus, Mars, Jupiter and Saturn. Like the Greeks, he resorted to the use of eccentrics, so that the center of the orbit of the Earth and that of the orbit of Saturn, for instance, did not coincide. Milton's famous description[1] of

> . . . the sphere
> With centric and eccentric scribbled o'er,
> Cycle and epicycle, orb in orb

fits Copernicus fully as well as Ptolemy.

To allow room for the deviations of planetary motions from a path absolutely restricted to one circle and the sun as its center, Kepler took his planetary spheres to possess thickness. The rubber of a rubber ball serves as an image; there is an outer and an inner spherical surface to the ball. This thickness was carefully computed so as to allow each sphere just enough play room for epicyclic and eccentric planetary behavior. In the thickened surface of each sphere the respective planet could follow the irregularities of motions peculiar to itself. Fig. 3 is taken from Kepler's "World Secret" and purports to be drawn to scale. The letter A represents the thickness of the sphere for Saturn, B the thickness for that of Jupiter, C that of Mars, D that of the Earth, E that of Venus. By this means the distance of Saturn from the sun was increased about 15 per cent. Allowing for the thickness of the spheres, Kepler found his system of polyhedra to satisfy his most sanguine expectations. Let us quote his numerical findings:

When the	Saturn	measures	Jupiter	577	But accord-	635	Chap. 9
inner	Jupiter	1000 radial	Mars	333	ing to Coper-	333	" 14
sphere	Mars	parts, then	Earth	795	nicus	757	" 19
of	Earth	one obtains	Venus	795	(Book V)	794	" 21, 22
	Venus	the outer	Mercury	577	it is	723	" 27
		sphere of		or			
				707			

We must pause a moment to study these figures. The test of Kepler's scheme is found in the numerical ratios computed from the observational data given in the great book of Copernicus, "The Revolution of Celestial Spheres," to which reference is made. The quotation involves five statements, of which the third is, "When the inner sphere of Mars measures 1,000 radial parts, then one obtains for the outer sphere of the Earth 795 (parts); but according to Copernicus (Book V) it is 757 (parts), Chap. 19." The agreement is close in some cases, somewhat wide of the mark in others. Let us quote Kepler's own interpretation: "See now how close corresponding numbers come to each other. For Mars and Venus they are the same. For the Earth and Mercury they are not much apart; only for Jupiter do they deviate strongly, which, however, will surprise no one in view of the tremendous distances." In case of Mercury he takes, not 577, but 707, which is "the radius of the circle inscribed in the square of the

[1] "Paradise Lost," Bk. VIII, lines, 82–5.

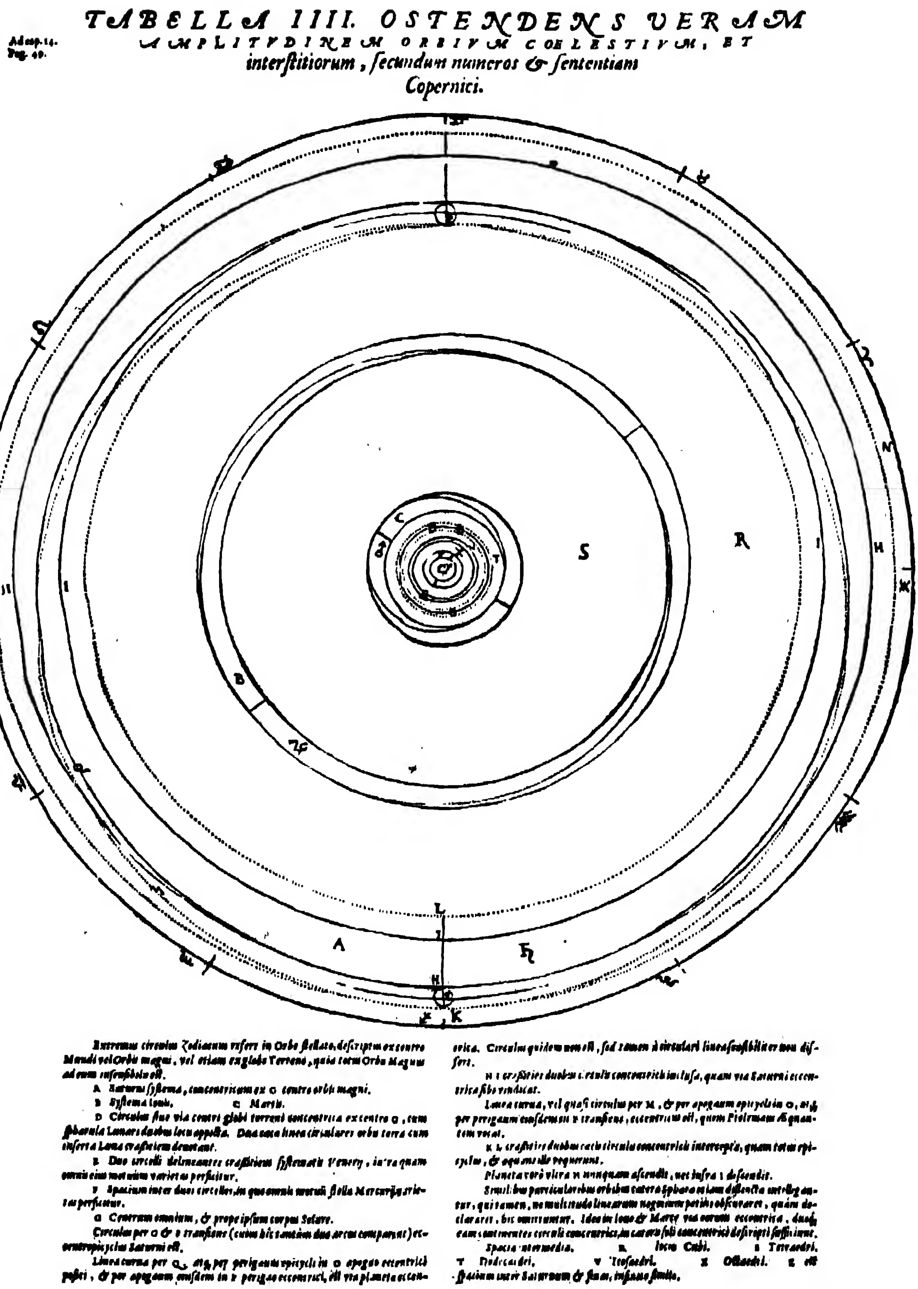


FIG. 3. A SECTION OF KEPLER'S MODIFIED COMBINATION OF SPHERES AND REGULAR SOLIDS

THE THICKNESS OF THE SPHERES PURPORTS HERE TO BE DRAWN TO SCALE. THE THICKNESS OF THE SPHERE CONTAINING THE ORBIT OF SATURN IS MARKED A, THAT OF JUPITER B, ETC.

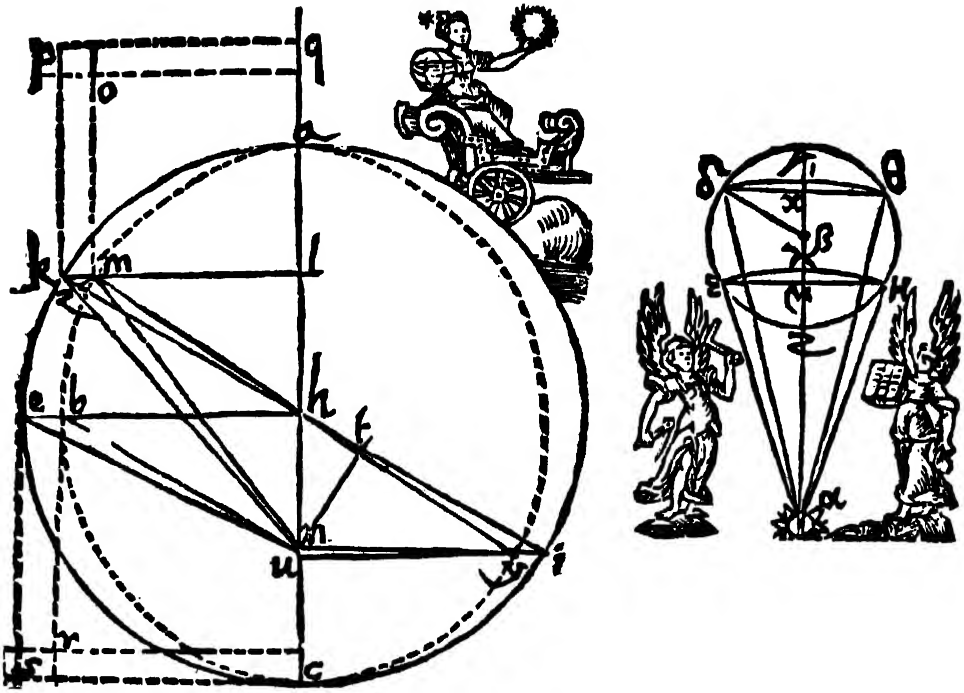


FIG. 4. THE ELLIPTIC ORBIT OF MARS

THIS DRAWING IS HERE SURMOUNTED BY VICTORY IN A TRIUMPHAL CHARIOT. IN LATER EDITIONS OF THE "ASTRONOMIA NOVA" THIS VICTORY AND CHARIOT ARE OMITTED. THE TWO ANGELIC FIGURES ON THE RIGHT MAY HAVE BEEN ADDED BY THE PRINTER FOR ARTISTIC EFFECT.

octahedron." This 707 is closer than 577 to the required 723.

The youthful Kepler had not yet come in contact with an accurate observer, like Tycho Brahe, and had not yet learned the need of closer agreement between theoretical and observational values. Kepler was satisfied. To him his polyhedra and sphere system was not a mere fancy, a dream of a phantastic imagination. To him it was the discovery of a real world secret, a *mysterium cosmographicum.* "I believe," says Kepler, "that it is through a dispensation of providence that I ascertained by accident what previously I could not reach by any amount of labor; I believe this the more, because I always prayed to God that He might let me succeed in my plans. . . . To describe in words the satisfaction derived from my discovery will never be possible. . . . Days and nights have I spent in computation, until I saw whether the imagined theorem agreed with the orbits of Copernicus, or whether the winds would carry away my joy."

We have dwelt upon this early pseudo-discovery of Kepler because it reveals the mental processes of Kepler and because he himself never doubted the truth of his discovery. In a second edition of his book brought out in 1621, or twenty-five years later, he is as positive of its worth as ever, and supplied it with numerous annotations.

Kepler's mental processes were the same in his great scientific discoveries of later date as in this early pseudo-discovery. But later, through the influence of Tycho Brahe, he had come to study probabilities of error and to set for him-

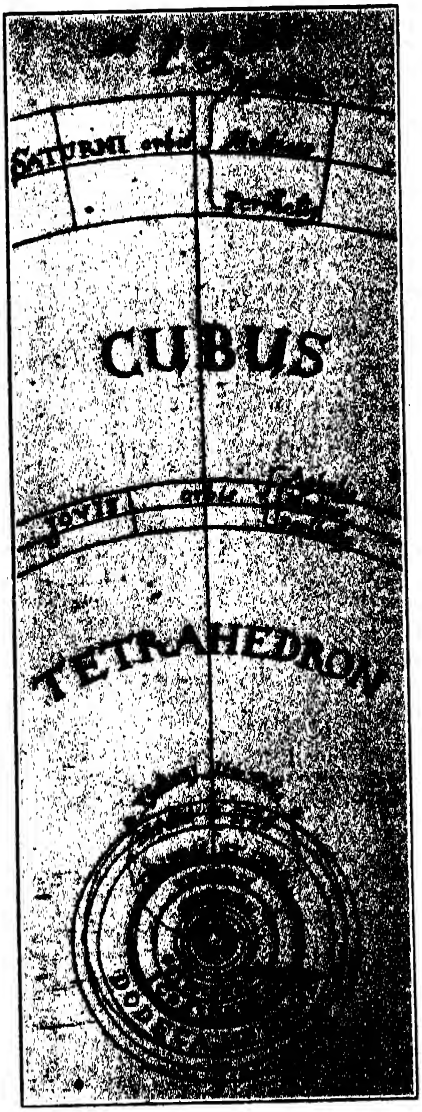


FIG. 5. A SECTION OF KEPLER'S MODIFIED COMBINATION OF SPHERES AND REGULAR POLYHEDRA

AS IT APPEARS IN THE "HARMONICES MUNDI," 1619. IT SHOWS THAT IN 1619 KEPLER WAS AS FIRM A BELIEVER AS HE HAD BEEN IN 1596 THAT THIS COMBINATION REVEALED THE WORLD SECRET.

self higher standards of agreement between hypothesis and fact. The idea at all times was to find geometrical relations agreeing with observed numerical values. What is the orbit of Mars? The circles of the Greeks and of Copernicus no longer afforded satisfactory agreement. At the first approach Kepler thought that he could settle this question in eight days, and even made a bet to that effect. But the eight days became several years. John Stuart Mill in his "Inductive Logic" speaks of the various hypothetical orbits assumed by Kepler and then rejected. Causal relations were as foreign to his thought as ever. The mystical element was still dominant. The entire year of 1604 was given to the trial of various egg-shaped orbits for Mars, no less than forty different assumptions being tested by lengthy computation. On December 18, 1604, he wrote to his friend Fabricius that the correct orbit lay between the circle and the oval, "as if the orbit of Mars were a perfect ellipse," but that he had not yet investigated this matter. At Easter in 1605 a chubby-formed orbit (*iter buccosum*) was found unsatisfactory. Somewhat later, after brain-racking effort, the truth stood resplendent before him. The orbit is an ellipse! "I was diverted most by the circumstance that although I cogitated and cast about almost to the point of distraction, I could not ascertain why the planet should, according to the evidence of the equations, prefer the elliptic path. . . . Oh foolish me!"[2] By further study, he became satisfied that the elliptic path is the only possible orbit of the planet Mars. In Fig. 4 behold the triumphal chariot heading the drawing of the Mars orbit!

Some one has called attention to Kepler's good fortune in having Tycho Brahe's observations, which were sufficiently accurate to render untenable the old hypothesis of epicycles and eccentrics and yet were not accurate enough to reveal the fact that the actual orbit of

[2] Kepler, "Astronomia nova," 1609, end of chapter 58.

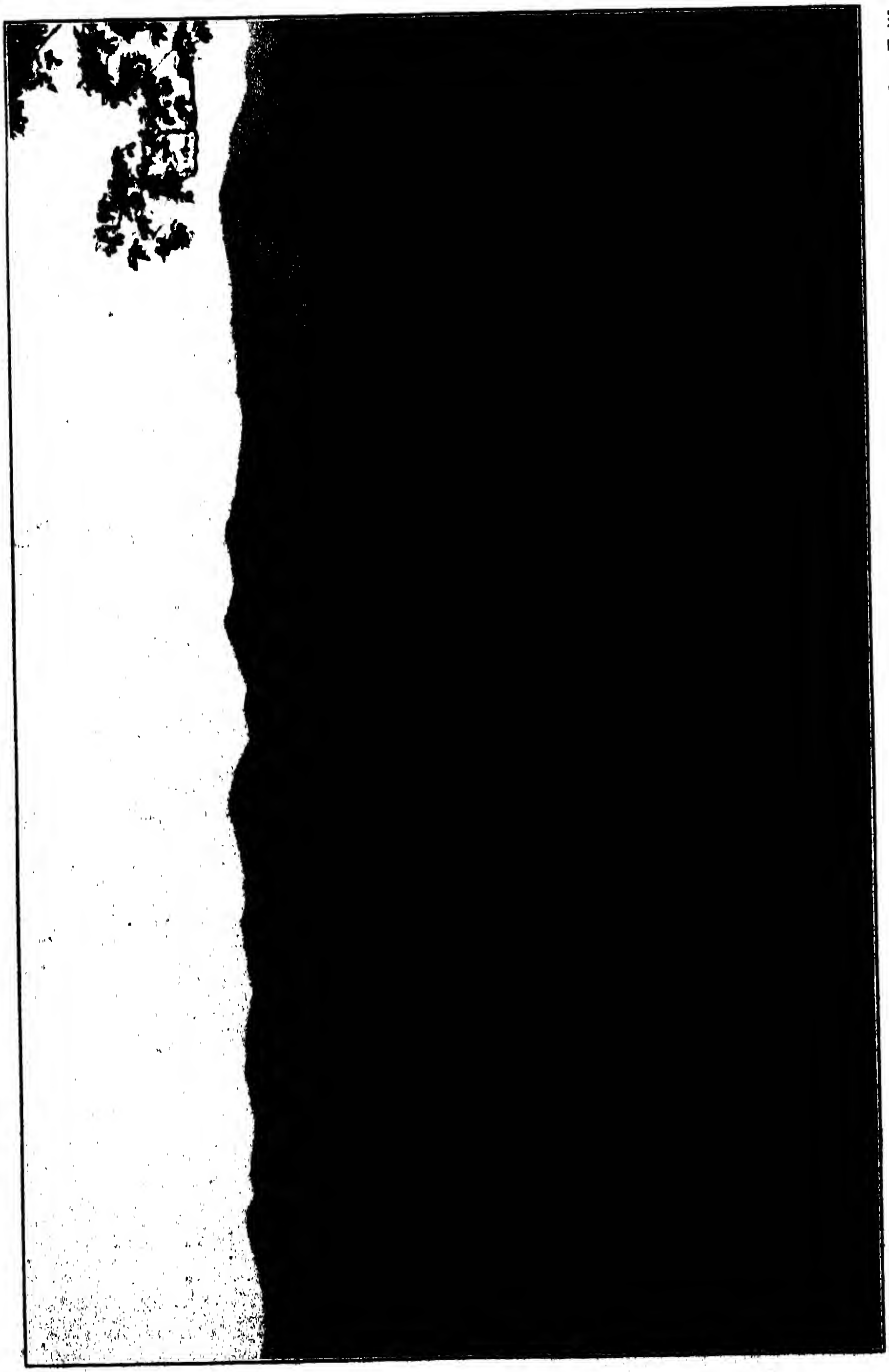
Mars is not accurately an ellipse, but an ellipse distorted by all sorts of perturbations due to the other planets. Observations of modern accuracy might have prevented Kepler's great discovery.

Kepler's "Astronomia nova," his great book of 1609, contains also the second law of planetary motion discovered by Kepler—the law according to which the radius vector drawn from the sun's center to the planet sweeps over equal areas in equal times. This law cost him comparatively little effort. It evolved naturally from his computations.[3] His third law, that the squares of the times of the revolution of any two planets around the sun are to each other as the cubes of the mean distances from the sun, was discovered much later, in 1618, and was published in his "Harmonices mundi" (Harmony of the World), 1619. Kepler regarded this work as the fuller development of his first publication, the "World Secret." Fig. 5, showing a section of the polyhedra and sphere combination and taken from the work of 1619, indicates that the belief in that explanation was as firm as in 1596. The fifth book of the "Harmony of the World" gives in the first two chapters elaborate drawings and explanations of the regular solids, and then a mystic search for hidden relationships between planetary distances and times of revolution. This search was for a long time barren of results. In fact, no one could know in advance that such a fixed relationship actually existed. At last Kepler was triumphant, as he relates in the following passage from Book V:

[3] "Astronomia nova," chapters 32 to 40.

> What I prophesied twenty-two years ago, as soon as I discovered the five solids among the heavenly bodies . . . what I had promised my friends in the title to this Book V which I named before I was sure of my discovery . . . that for which I joined Tycho Brahe, and for which I settled in Prague, that indeed, by the Most Benevolent God . . . I have at last brought to light and recognized its truth beyond my most sanguine expectations. . . . It is not eighteen months since I got the first glimpse of light, not three months since the dawn, very few days since the unveiled sun, most admirable to behold, burst upon me. Nothing dampens my ardor. It pleases me to indulge in my sacred fury, it pleases me to exult in triumph before mortal men, by the frank confession that I have stolen the golden vases of the Egyptians, to build a tabernacle to my God, far away from the borders of Egypt. If you forgive me, I shall rejoice; if you are inflamed with anger, I can bear it. The die is cast, I write the book, to be read, either now or by posterity. Which, I care not. It may well wait a century for a reader, as long as God waited six thousand years for a discoverer.

Kepler's discoveries were made in the face of every form of discouragement—frail health, financial embarrassments, war conditions, family troubles and religious persecutions. The achievement of great results under great difficulties entitles him to a place among the immortals.



—*Photograph by Arthur Keith*

PLOTT BALSAM MOUNTAINS, TENNESSEE

PHYSIOGRAPHIC CONTRASTS, EAST AND WEST

By Professor Emeritus W. M. DAVIS

HARVARD UNIVERSITY

Introduction

There are many commonplace matters which must be consciously analyzed before we become aware of their essentially marvelous nature and of their bearing on the grand philosophy of evolution. The ceaseless and usually involuntary inhalation of the breath of life, which, like the altogether involuntary beating of the heart, is continued uninterruptedly from birth to death, is a good example. We are hardly more aware of it while awake than when asleep; yet inasmuch as we, like all living organisms, plant as well as animal, thereby gain the energy needed for our life work, it is reasonable to base on the universality of this ordinary but really wonderful process the great inference that free atmospheric oxygen has always been available for the use of living beings ever since life began on the earth. That is a large lesson to draw from a simple text.

The observance of a lunar time schedule by seaweeds that live on a shallow rocky shore is a simpler commonplace. They lie down twice a lunar day, when the withdrawal of the sea water leaves them unsupported at low tide, but float up again when the water returns at high tide. This is not at all analogous to the habit adopted by most land plants of standing up all the time, or by many land animals of lying down for repose during the nocturnal half of the solar day; it is a consequence of the physical conditions under which the seaweeds have been evolved: for inasmuch as the heavy medium in which they grow buoys them up sufficiently while it is present, they have not developed stiff stems to support their weight when it is absent; so then they lie down.

The superb phenomena of sunrise and sunset, trite to too many of us because of their daily repetition, merit attentive observation once in a while in order that the arrangement of their color effects should be consciously recognized; and while they are thus observed it is worth remembering that their display of colors constitutes a vast natural experiment in optics which the sun has been performing on our atmosphere for ages and ages. I venture to believe that most readers of this article, who may think that they already know what colors are to be seen at these critical epochs of the day, can not give a fair description, much less an adequate explanation of them. How many know, for example, that as the reddened sun sinks below the western horizon of a cloudless sky at sunset, the cold-blue shadow of the earth on the sky rises correspondingly over the eastern horizon and is visible there with increasing breadth and diminishing definition for about half an hour before the whole sky darkens?

It is not, however, about the heavenly contrasts of earth shadow and sunset glow, east and west, that I propose here to write, but about the more earthly contrasts between the valleys of our Atlantic and Pacific slopes. They are thoroughly commonplace affairs to their local inhabitants in our two regions, and few such home-dwellers have any clear idea of the contrasts that the Eastern and Western valleys present. Only the more observant of our transcontinental travelers may have already noticed how unlike they are; but to a much larger number of Americans, otherwise fairly well informed on the geography of our country, the unlikeness is known imperfectly, if at all.

Eastern and Western Valleys

The leading characteristic of our Eastern valleys is their long continuity, in

consequence of which the Eastern rivers carry to the Atlantic in the most normal fashion all the land waste that is delivered to them from their drainage areas by rill wash and soil creep, in a persevering effort everywhere to degrade the land surface. On the other hand, the characteristic of our Western valleys is their prevailing discontinuity, in consequence of which the Western rivers repeatedly fail to carry out the expectations with which their enterprising headwaters set to work; for a great part of the land waste there received from the highland slopes, the normal goal of which should be the Pacific, is laid down on valleyless open ground before reaching the ocean. These contrasted characteristics deserve to be set forth in some detail.

Valleys of the Appalachians

Let us imagine ourselves standing on the crest of the Blue Ridge, the main divide of the Appalachian highlands in Virginia or North Carolina, whence so many valleys lead by direct courses to the Atlantic shore or along more roundabout courses by way of the Mississippi to the Gulf of Mexico. All these valleys are everywhere sunk, along the entire hundred- or thousand-mile lengths of their rivers, below the general upland levels of the region that they drain. Their ramifications are often most intricate and labyrinthine; yet all the valleys have, except close to their mouths in the lowest-lying coastal plain, well-defined side-slopes leading down from the adjacent uplands to the stream lines; they are all, moreover, genuine valleys of erosion in the sense of being linear depressions, excavated under the leadership of their streams; they are all systematically arranged, twig joining branch and branch joining trunk on the way to the sea, and they all possess a continuous down-stream slope from head to mouth. A resident in this region might well gain the belief that valleys are an invariable accompaniment of rivers. Here if anywhere in the world may application be found for Playfair's far-reaching generalization of 1802:

> Every river appears to consist of a main trunk, fed from a variety of branches, each running in a valley proportioned to its size, and all of them together forming a system of vallies, communicating with one another, and having such a nice adjustment of their declivities, that none of them join the principal valley, either on too high or too low a level; a circumstance which would be infinitely improbable, if each of these vallies were not the work of the stream that flows in it.[1]

The fine phrasing of this wise statement goes well with its clarity and fair-mindedness. And yet so slowly were the erosional processes of land sculpture given recognition in the first half of the nineteenth century that so keen an observer as Charles Darwin still held, forty years after Playfair's time, to the older view that river valleys were as a rule carved by marine agencies as the lands rose from beneath the sea!

The Mobility of Water

It is not alone to the efficacy of rain and rivers in the carving of the land surface that the long Appalachian valleys testify: they bear witness also to another matter of great terrestrial significance, namely, to the marvelous mobility of water by which the carving of the lands is so largely guided. The slopes given to the Appalachian region at the time of its last upheaval, when a broad up-arching of the earth's crust took place between the Mississippi and the Atlantic coast, are extremely gentle, and it is wholly because of the great mobility of water that the Appalachian rivers have been able to cut down their valleys, except near the headwaters, to gentler slopes still.

A thousand-mile profile drawn on true scale across the Appalachian highlands, not to show the altitudes of the mountains and ridges but to measure the up-arching last experienced by them, would have almost imperceptible declivities, east

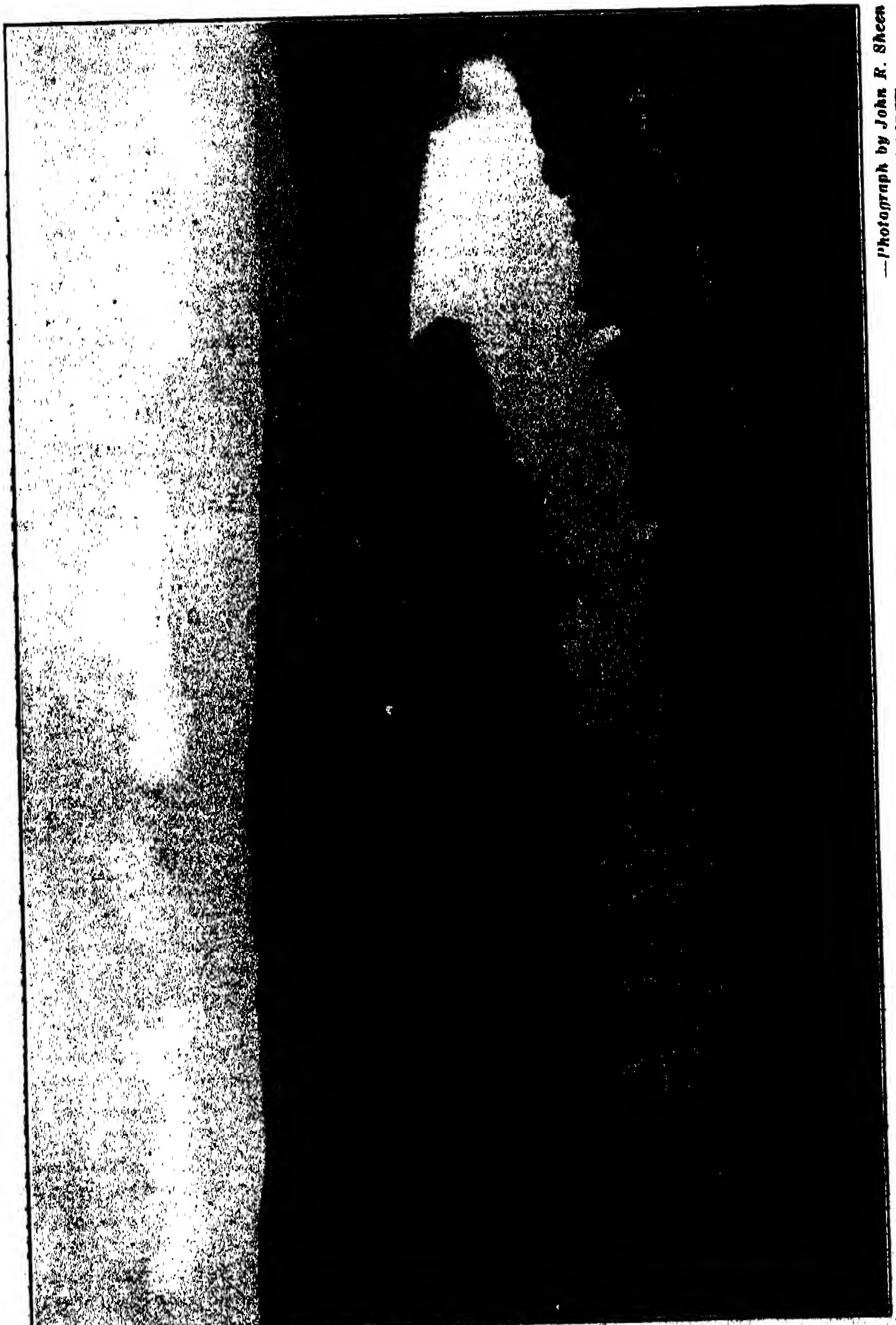
[1] "Illustrations of the Huttonian Theory," p. 102, Edinburgh, 1802.

and west; yet the valleys have everywhere, except near their heads, been cut down beneath the gently up-arched surface to fainter declivities still! A fall or gradient of a few feet to a mile, a gradient quite imperceptible to the unaided eye, is sufficient to keep the rivers running, even though their flow is impeded by the work they have to do in lifting and bearing along a certain amount of fine detritus in suspension and in sweeping coarser detritus along their beds. The point is, therefore, that the valleys are worn down along their stream lines to just such declivities as will give their rivers just that velocity which enables them to do just the transportational work that they have to do; that is, they are "at grade." They can, under present conditions, neither wear down nor build up, neither degrade nor aggrade the greater part of their courses. Falls and rapids are still common in the as yet ungraded headwaters of many streams, but it is only by way of rare exception that a close adjustment of stream gradient to stream duty has not been brought about along the middle and lower courses. The exceptions are rare, local and small, as at Muscle Shoals of the Tennessee where that river flows from the state of its own name into Alabama; at the falls of the Ohio on a reef of resistant limestone at Louisville, Kentucky; at the riffles of the Susquehanna on sills of resistant sandstone above Harrisburg, Pennsylvania, and, greatest of all, at the falls of the Potomac next above Washington, where a recent uplift has set that river again at work to degrade its course on resistant crystalline rocks. The rule of smooth gradients along water-courses also has local exceptions of quite another kind in the cavernous limestone district of central Kentucky, where branch valleys are frequently left "hanging" over the deeper main valleys, because the branch streams have abandoned their surface channels and taken to underground passages.

Equable Upheaval of the Appalachian Highlands

The broad smoothness of the Appalachian up-arching and the gentleness of its declivities, in consequence of which the valleys are so nicely excavated to moderate or small depths by their mobile rivers, resulted from the exceptionally equable manner in which the telluric forces that deform the earth's crust have acted in recent geological time upon that large fraction of our country which stretches from the Mississippi to the Atlantic seaboard, for only in consequence of a broadly even uplift of moderate measure could the rivers have been compelled everywhere to erode their valleys to moderate depth. If the uplift had been irregular, with sags between heaves, deposition in the sags would have alternated with erosion across the heaves, and the valleys would have been discontinuous; but the Appalachian valleys nowhere show such discontinuity; they are consistently eroded below the highlands and uplands all along their courses. This region therefore gives good warrant for the belief that the deformation of the earth's crust may proceed, in certain parts of its spheroidal surface, in a surprisingly equable manner over an area of subcontinental extent. This kind of deformation has therefore been called epirogenic or continent-making, in contrast to deformation of a more local and irregular nature, which is known as orogenic or mountain-making.

The systematic excavation of the Appalachian valleys below the uplifted land surface that they drain shows also that rivers object to the maintenance of even so moderate a continental altitude as was given to their region by its latest broad up-arching; and the manner in which the rivers, after cutting down their valley floors to as faint a gradient as possible, continue to take part in the general degradation of the region by carrying away the detritus that is weathered on the valley-side slopes and delivered to the



—*Photograph by John R. Sheen*

NORTH FORK OF SHENANDOAH RIVER, VIRGINIA. MASSANUTTEN MOUNTAINS IN THE DISTANCE

water-courses by rill wash and soil creep shows how determined the rivers are to reduce highlands to lowlands. Small amounts of detritus are, truly enough, temporarily deposited in valley-floor flood plains, but they are trifling in volume compared to the vastly greater amounts that are carried down stream and dutifully delivered to the ocean. Thus, if no disturbing upheaval occurs in the future, the whole region will be eventually worn down to a nearly featureless plain, everywhere sloping faintly to its streams, while the streams slope more faintly still to the ocean; for to that end the patient processes of weathering and streaming[2] are unceasingly at work.

But the Appalachian rivers are not engaged to-day for the first time in this long-lasting degradational task. They have had at least two tries at it before, each try having been interrupted after a time by a broad up-arching. This is known because the present rather narrow and shallow valleys are repeatedly found to be excavated along the higher-standing floors of broader valleys; and again because these broader valleys lie below uplands that bear the marks of having formerly been parts of an extensive lowland of degradation.[3] The first try was by far the longest undisturbed and hence the most successful of the three; the third try, now in progress, is thus far of relatively brief duration and small accomplishment; the second was of intermediate value in time and in work.

Three-Cycle Landscapes

There are many delightful views along the valleys of the Susquehanna and

[2] Streaming is here used to denote the work of streams, just as weathering denotes the work of the weather.

[3] The somewhat technical evidence to this end was first set forth about forty years ago in several almost contemporaneous papers: one by W. J. McGee, "Three Formations of the Middle Atlantic Slope," *Amer. Journ. Sci.*, 35: 120–143, etc., 1888; another by Bailey Willis, "Round about Asheville," *Nat. Geogr. Mag.*, 1: 291–300, 1889; a third by the present writer, "Rivers and Valleys of Pennsylvania," *ibid.*, 1: 183–258, 1889.

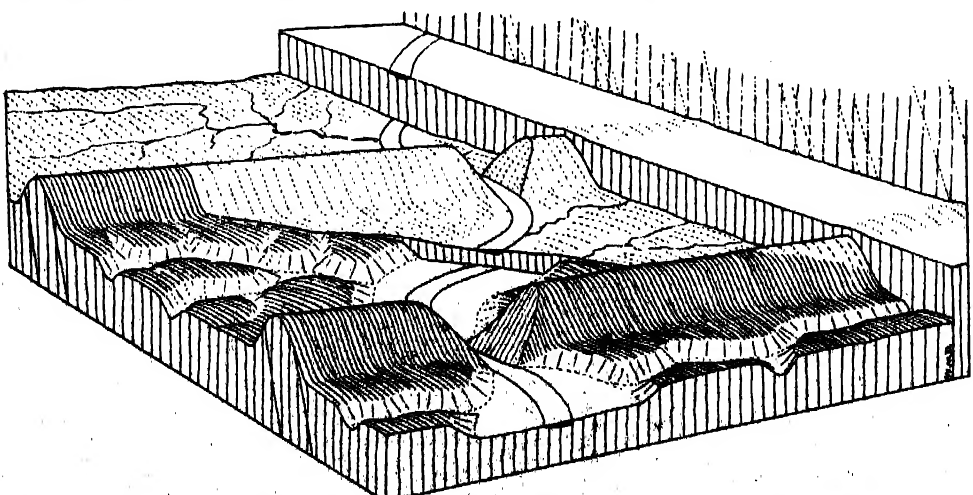


FIG. 1. DIAGRAM OF A THREE-CYCLE APPALACHIAN LANDSCAPE

The smoothly degraded lowland of the first cycle is shown, broadly uplifted, in an unshaded strip on the right. In the background the inter-ridge, weak-rock lowlands, worn down in the second cycle between the surviving hard-rock ridges, are shaded with dotted lines. The valleys eroded in the inter-ridge lowlands after a second regional uplift during the third cycle are shown, unshaded, in the foreground below full-lined uplands and ridges.

Juniata in central Pennsylvania, of the Potomac and Shenandoah in Old Virginia and of the Tennessee and the French Broad in the eastern part of their state, where the threefold composition of the landscape, developed on the steeply inclined strata of the deformed Appalachian belt, is clearly recognizable, as simplified and summarized in Fig. 1. The high but even skylines of the many hard-rock ridges, all of fairly accordant altitude though of very different structure, retain traces of the broad lowland, shown in an uplifted position on the right of the figure, to which the whole region was, long after its great deformation, reduced in a nearly complete cycle of erosion, as the time-period of that exceptionally successful try may be called. The lower, inter-ridge areas, worn down on weaker rocks and shaded with dotted lines in the middle background, preserve good-sized remains of a second lowland, to which the first was, after its broad upheaval, reduced during the second cycle of erosion, except along its hard-rock belts. The present, well-opened valley floors, excavated in the foreground beneath the full-lined, inter-ridge uplands, exhibit the work of the third cycle, introduced by a moderate upheaval which interrupted the continuation of the second cycle and which is as yet not very far advanced in its total work.

It is by taking the levels of the now high-standing, hard-rock ridge crests, which survive with small modification from the broad lowland produced in the long uninterrupted first cycle of degradation, and of the broad valley floors that were worn down on the weaker strata during the shorter second cycle, that warrant is found for the statements made above as to the smoothness of the broad up-archings suffered by the Appalachian region. This has been best done by Hayes and Campbell,[4] experienced members of the U. S. Geological Survey, who thirty-five years ago published two contour maps, indicating the altitudes at which they had found uplifted and little modified parts of the earlier surfaces in the southern Appalachian region; and from this it appears clearly enough that the earliest surface was raised broadly into an unwrinkled highland, with gentle slopes to the Atlantic coast and to the Mississippi River, when the first degradational try was succeeded by the second; and that a movement of similar nature but of less amount and of more recent date determined the change from the second try to the third, now current. Additional minor movements have taken place but they do not significantly affect this summary and can not be considered here. To far-reaching conclusions of this kind has a critical study of the well-ordered Appalachian valleys led.

[4] C. W. Hayes and M. R. Campbell, "Geomorphology of the Southern Appalachians," *Nat. Geogr. Mag.*, 6: 63–126, 1895.

The Atlantic Coastal Plain

It was in intimate association with these equable epirogenic upheavals of the Appalachian highlands, and with others of similar nature but of earlier date, that a belt of smoothly laid, sea-floor sediments was added to our eastern continental border, constituting the Atlantic and Gulf coastal plain, which everywhere sloped gently to the retreating shoreline. It is noteworthy that the plain, which now narrows northward and ends at New York Harbor, originally extended much farther northeast, probably to Nova Scotia at least; and that after it had gained that great extension and had suffered appropriate valley erosion by the many rivers that were prolonged across it from the higher backland, the northeast part of the plain experienced an increasing submergence. It retained full width in South Carolina, but it was somewhat narrowed in North Carolina, where the lower parts of its chief valleys are submerged in Albemarle and Pamlico sounds; it was more narrowed in tide-water Virginia, where its chief valleys are embayed across its

whole breadth, and it was tapered off to a point in New Jersey. Farther on, only insular remnants of it are seen, more or less moraine-crowned, in Long Island, Block Island, Marthas Vineyard and Nantucket. Farther on still, the ocean overlaps on the backland from Cape Cod to Nova Scotia; but features of the coastal plain are believed to be indicated by soundings in the Gulf of Maine.[5]

If we exclude the local up-swellings, known as "salt domes," in the coastal plain of Texas, it may be said that the whole length and breadth of the Atlantic and Gulf coastal plain has emerged with an unwrinkled seaward slope, so gentle as to be unrecognizable by the unaided eye. Hence the equability of upheaval already found for the Appalachian highland belt persists in the added area of its maritime border. The continuity of valley erosion persists also, for all the rivers that flow from the backland highlands and uplands across the foreland coastal plain have there eroded extensions of the valleys that they had previously excavated in the older backland, except that, in the lowest part of the southern plain near the sea, the valleys are so little incised as to be hardly perceptible; at times of heavy rain the flood of one river may there escape from its valley and stray across the low plain to that of a neighboring, less flooded river. It appears, therefore, that the addition of the coastal plain around the seaward margin of the Appalachian highland has resulted, except in New England where the plain has been resubmerged and the rivers have been betrunked, in a duplex habit of valley development. For so long as the rivers are flowing in the more elevated highlands of older and harder rocks their valleys are deeper and narrower, but where the same rivers cross the coastal plain of younger and weaker strata their valleys are shallower and broader. This duplex development is, however, altogether normal and orthodox, for what can be more proper than for a river to extend its length from an earlier-established continental area across a new addition to the continent caused by the emergence of an adjoining sea floor! There is therefore no derogatory implication intended in characterizing such development as duplicity.

[5] D. W. Johnson, "The New England-Acadian Shoreline," p. 295. New York, 1925.

Earlier History of the Appalachian Belt

The eastern part of our continent has not always behaved in the equable manner above indicated. In the remotest primeval times, the earth's crust there suffered tremendously tortuous convolutions, best shown now in the ancient crystalline rocks of the Laurentian highlands of eastern Canada. In later but still ancient geological times, a long and broad belt of heavy stratified formations bordering the Atlantic was at more than one date laterally compressed into gigantic folds and shoved into vast overthrusts, as if by the direct and primary application of a northwestward compressional force to their previously horizontal structure. It was then that the northeast-southwest trends of the deformed Appalachian strata were developed. In a medieval period, certain narrower Atlantic slope zones were down-warped or down-broken into troughs, in which heavy sediments were laid down in association with repeated lava intrusions and outpourings; and then the sediments and the lava sheets were broken into long blocks and the blocks were diversely tilted by disorderly movements of their foundation. In this case it seems as if the heavy cover of sediments and lavas had to adjust themselves to secondary dislocational forces which arose from a deforming application of primary forces to deeper-seated masses. In consequence of each one of all these disturbances, the rivers of their times presumably eroded valleys in the uplifted areas and de-

posited detritus in the depressed areas. Some Appalachian rivers then at work may, after an active youth of heaved-highland trenching and sag-basin filling, have combined their discontinuous valleys in deeper-cut and maturely integrated valley-systems of a considerable extension; but they could not have possessed through all their life history and through their entire length the five hundred- or one thousand-mile continuity of erosional excavation which characterizes the present valleys. Not until the orogenic crustal movements of earlier times had been tamed down to modern epirogenic equability could valleys like those of to-day be eroded; not until then did a steady-going, oceanward transportation of land-waste by our rivers become possible, nowhere defeated even temporarily by deposition in down-sagging depressions.

The Appalachian region is therefore to-day one of those terrestrial areas in which valleys of continuous erosion are a leading characteristic. Observers whose home is there and who have not traveled elsewhere might, as already intimated, believe themselves justified in concluding that all rivers follow valleys of erosion all along their length, as theirs do; but the belief would prove faulty as we shall now see.

The Northeastern Lacustrine Region

The generalization that all our Atlantic rivers have a continuous and steady flow along graded valley floors of continuous fall is manifestly inapplicable to a great area of northeastern America, where the rivers are repeatedly hurried in ungraded rapids or cascades or halted in quiescent lakes. The trunk river of the St. Lawrence system is the most famous example of this kind, for it has rapids at the outlet of Lake Superior and a high cataract between Lakes Erie and Ontario, and a large fraction of its total length is expanded in great, still-standing water bodies. All the rivers of the Laurentian highland partake of this cascading acceleration and lacustrine retardation, although their falls are seldom high enough to be renowned and their lakes do not often occupy an excessive fraction of their length. The cause for these imperfections of valley development is not to be found (unless possibly in the exceptionally deep basin of Lake Superior) in an irregular deformation of the earth's crust at so recent a date that the rivers have not been able subsequently to develop regularized courses, for the geological history of the northeastern region shows that it has been quiescent for a much longer period than the Appalachian belt has been. Hence the rivers there ought to have valleys as well developed as those of the rivers farther south; and so they probably had until their region came to be in late geological time severely glaciated. Slow-creeping ice-sheets of Canadian origin then scoured the land surface over which they spread, and dragged away so much of the scourings that, after the last ice-sheet had disappeared, the well-ordered preglacial valleys were all disordered. The region was left with many scoured-out hollows or basins, small and large, and with many irregular deposits of glacial detritus. Hence when the last ice-sheet melted away and rivers again took possession of the surface, they repeatedly had to adopt new lines of flow, along which new valleys were to be developed; and the small progress that they have as yet made in this task proves that the disappearance of the last ice-sheet was of relatively recent date, as rivers look at time. Thus briefly must we here dispose of a great American problem.

The Great Plains

Now let us leave eastern North America and travel westward across the central treeless belt of the Great Plains. We shall there again find that the main valleys exhibit a thousand-mile continuity of laterally enclosed excavation below broad uplands on either side, thus suggesting that the eastward slant of the

plains is due to a broad and equable upheaval, much like that of the Appalachian belt. But it should be noted that, in eastern Colorado and western Kansas, the inter-valley uplands were built up, before the present valleys were eroded across them, by the deposition of detritus that was river-swept from the Rocky Mountains and spread out at halfway stations, instead of being properly carried all the way to the Mississippi and the Gulf. The fluviatile deposits do not, however, imply a sagging of the plains area so much as a slight change in the régime of the long rivers, for in a masterly account of these plains by W. D. Johnson[6] he makes it probable that their aggradation was due simply to a climatic variation of rainfall rather than to any movement, epirogenic or orogenic, of the earth's crust thereabouts.

Intermont Basin Plains of the Cordilleran Region

If we next enter the mountainous area of the western third of our country, a new order of things is encountered. Intermont troughs and basins, filled up to nearly level surfaces with detritus washed down from valleys in the enclosing mountain ranges, are here of frequent occurrence. They may measure from ten to fifty miles across and the larger ones have lengths of a hundred miles or more. They are true areas of sagging, in contrast to the mountains which are as truly areas of upheaval; that is, the recent renewal of crustal deformation in this great region has been dominantly of an irregular or orogenic nature, even if superposed, as is likely enough, upon broader movements of an epirogenic nature.

It should be understood, however, that the recent range- and basin-making deformations are of moderate measure compared to the much greater deformation that the Rocky Mountain region had previously suffered; also that the mountainous topography which must have first resulted from the erosion of the earlier deformations had been greatly reduced by advanced degradation before the later and more moderate deformation took place and produced the present mountain belts. Excellent exemplifications of these general truths are to be found in the "Three-Forks Folio, Montana," of the U. S. Geological Survey, by A. C. Peale, which gives clear illustration of both the earlier and later deformations, as well as of the vast effects of the long-continued erosion that followed the earlier deformation and of the lesser effects of erosion on the heaves and of deposition in the sags associated with the later deformation.

This irregular style of mountain-and-basin-making deformation has recently prevailed all across the Cordilleran region, from the Rocky Mountain front to the Pacific coast, but most of the lava-covered region of the northwest must be excepted from this too-sweeping statement, as will be further told in a later paragraph. In consequence of its irregular orogenic deformation, the valleys of this vast area are prevailingly and strikingly discontinuous, much more so, indeed, than the rivers, for in the depressed troughs and basins, which are to be counted by the score, the rivers have been obliged to act as depositing instead of as eroding agents and have therefore built up detrital plains, and while the plains are in process of formation, valleys are absent from them. True, valleys are eroded in abundance in various upheaved mountain ranges by the upper courses of the rivers, and it is from these rock-cut valleys that the detritus has been derived for the infillings of the intermont depressions with plains of aggradation; and although the rivers have an orthodox continuity across the plains while aggradation is in progress, the valleys have not. The valleys end at the base of the enclosing

[6] W. D. Johnson, "The High Plains and their Utilization," 21 Ann. Rept. U. S. Geol. Surv., 1901, Pt. 4, 601–741.

mountains, and the rivers run forward on the gentle slope of the intermont plains not in valleys but only in channels. This is an important lesson which the Easterner, accustomed to an orthodox continuity of valleys and rivers, must learn if he is to understand the heterodox physiography of the West. It is the lesson taught by rivers that flow from well-enclosed valleys, deep cut in mountain slopes, out upon channeled plains: it is the lesson of mountain-valley and plain-channel rivers.

Basin Plains and Alluvial Fans

The basin plains of the Cordilleran region are peculiar in that they do not lie between neighboring mountain ranges in intermont fashion, but are completely surrounded by mountains so that they deserve to be called intramont. They are by no means perfectly level because, in their most typical form, they consist of as many low-grade, laterally confluent, detrital cones or "fans" as there are valleys opening from the mountains which surround them. Each fan spreads forward in a faintly concave slope from its apex in a valley mouth, and all join in a plain over the central area, as shown diagrammatically in Fig. 2. A suggestive analogy may be drawn between waste-filled basins of this kind and water-filled basins or lakes. The first may be called lakes of waste; the second are lakes of water; or better said, the first are lakes of water-logged waste, the second are lakes of waste-free water. In both there must be a fan-like slope of the surface away from every stream-mouth of inflow; but in water-lakes the fan-slope is imperceptible, while in waste-lakes it is visible. The forward slope of each water-fan in a water-lake must be just sufficient to cause the water to move away from the stream mouth as fast as it is delivered there; the forward slope of a waste-fan in a waste-lake must have the gradient needed by the fan-building stream for the transportation of its detritus.

The shallow stream channel which follows down one radius or another of a detrital fan on an intermont basin plain is usually subdivided by many smaller or larger lozenge-shaped gravel and sand shoals or islets in a complicated, interlacing or braided fashion of varying pattern with every flood. The braided fan-channel is, moreover, frequently shifted, especially at times of flood, from one radius of the fan, where up-building has been going on for a while, to another radius where up-building is less advanced: thus every part of the fan comes to be about equally aggraded. The coarser detritus, torrent-swept from the mountains and sometimes of large-boulder texture, is mostly deposited on the slightly steeper slope of the fan-apex near the mountain border; the finer detritus is washed forward to the mid-basin plain, where the slope is hardly perceptible. Fans of from three

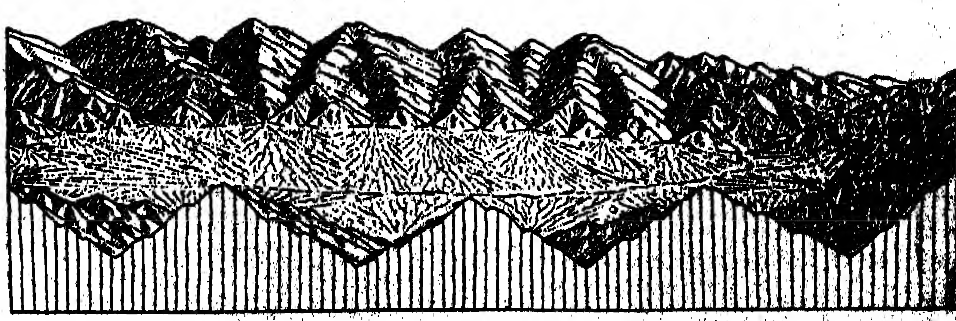


FIG. 2. AN AGGRADED INTRAMONT BASIN
COMPOSED OF MANY LATERALLY CONFLUENT ALLUVIAL FANS AND DRAINED BY AN OUTFLOWING RIVER.

to five miles radius, a thousand feet higher at the apex next to the mountains than on the mid-plain, are not uncommon. Small streams, especially where they descend from high mountains, may build relatively steep-slanting fans, with apical slopes of 5° or 10°; their forward reach of half a mile or so is overlapped on either side by larger fans of longer reach and lower declivity, and these all blend indistinguishably in the mid-basin plain.

A good-sized river forms a fan of lowest gradient, and when such a river shifts its course laterally, it may undercut the shorter and steeper fans of neighboring smaller streams, which thereupon trench true little valleys in the fans that they had previously been building. Conversely, when the larger river swings away again, the small streams retaliate for the snubbing of their fans by refilling the little valleys and building new fans out as far as possible on the abandoned sector of the large-river fan. These peculiar forms are described in some detail because, while they occur by the thousand, small and large, in the Cordilleran region, they are hardly known at all in normally eroded regions of epirogenic equability. They may, to be sure, be faintly developed in such regions where a tributary stream runs out on the flood plain of a trunk river, but such a fan is usually so inconspicuous as to be hardly noticeable. The best fans that I have seen in the eastern United States are in the White Mountains, where, in consequence of the overdeepening of certain main valleys by the special process of glacial erosion in the recently past Glacial period, detritus is deposited on the deepened valley floors in the form of fans by the outwash of hanging lateral valleys.

River Outlets of Intramont Basins

In the Rocky Mountains proper—that is, in the eastern part of the broad Cordilleran belt—where the rainfall, although not heavy, is more plentiful than in the arid Southwest, the intramont basins are all drained outward on one side or another through deep notches in the enclosing mountains. In such cases, all the centripetally inflowing streams unite on the basin floor in a trunk river, which then, as in Fig. 2, flows centrifugally outward through a notch or gorge of escape, or "gate of the mountains," as it is sometimes called. In explanation of such notches the old idea was that, the mountains being suddenly raised around a non-raised basin area, a lake gathered in the basin and rose until it reached the lowest pass in the mountain rim; there the lake-waters overflowed and the outflowing river cut down its notch deeper and deeper until the lake was drained away and the lake-bottom sediments were revealed as a basin plain. The newer idea, adopted when it came to be believed that mountain ranges rise slowly instead of rapidly, is that, even while a basin-making deformation is in progress, a pre-existent river, perhaps more or less shifted to a new course by the slow writhing and rising of its drainage area, persistently cuts down a notch or gorge of outflow across a mountain-heave, while it as persistently fills up a sagging basin next up stream with detritus supplied by valley-eroding headwaters in the surrounding mountains. At times of slightly faster deformation a shallow lake may overspread more or less of the aggrading basin-plain; and then for a time nearly level, fine-grained, lake-laid sediments will accumulate on the previously river-laid deposits; but at times of slower deformation, the shallow lake will be filled with detritus, and coarser, irregularly bedded, stream-laid deposits will accumulate in detrital fans, all sloping to the notch of trunk-river outflow.

Later on, when deformation becomes very slow or ceases altogether, the continued deepening of the notch of outflow by the escaping trunk river may cause it to cut a valley in the basin plain and also cause all the centripetal tributary

streams to trench their fans along whatever fan radius they happened to be flowing when the entrenchment began. In such cases, which now prevail in the Rocky Mountains, the relatively deep, steep-sided, rock-bound valleys of the headwater streams in the basin-enclosing mountains will be continued by shallower and broader gravel-bound valleys in the basin plain, and the plain will no longer be valleyless. In other words, the valleys will have gained a duplex development, somewhat like that of the Appalachian valleys where they are continued from the hard-rock highlands to the weaker strata of the coastal plain; but while the duplex habit of the Appalachian valleys is of orthodox sequence, always possessing hard-rock, up-stream features followed by weak-rock, downstream features, the habit of the Rocky Mountain valleys is not simply duplex but complex and disorderly, for there, after the streams leave the deep upper, hard-rock valleys and flow along the open, shallow, weak-gravel valleys in the basin floor, they characteristically return to hard-rock narrows, deep-cut through the mountain range at the basin outlet. They may, indeed, exhibit a multiplex succession of such alternations, as they pass from one basin through a range-gorge to another basin, and so on; but they may finally, after escaping from the mountains, continue in valleys of moderate depth through strata of intermediate age in their long course across the Great Plains. This is to-day the case with the upper branches of the Missouri, which drain several intermont basins in the Rocky Mountains of Montana. Hence there, while the valleys have gained a multiplex continuity equal to that of their rivers, they fail to show the simple orthodox duplicity of the Appalachian rivers.

Antecedent Rivers

Persistent, basin-draining rivers of the kind above described have been called antecedent, because their origin was antecedent to that of the locally uplifted ranges which they trench. Although the cross-range valleys of such trunk rivers are by no means so common as the shorter, range-side valleys of many new-formed headwater streams, they are, like the shorter valleys, highly characteristic of the orogenic diversity of Western deformation, in contrast to the epirogenic equability of the broad Eastern uplifts. If the East ever had any antecedent rivers, it must have been at the time, long ago, when it also was irregularly deformed, like the West of to-day.

Powell, famous one-armed explorer of the Colorado Canyon and subsequently able director of the U. S. Geological Survey, is generally credited with having been the originator of the idea that rivers may have persisted in their courses against unfavorable deformation. His type example was Green River, a main upper tributary of the Colorado, in its deep canyon through the east-west Uinta Range of southeastern Utah;[7] but although he gave a vivid account of it and proposed the catching name, antecedent, for rivers of its kind, his classic example is now regarded as not of antecedent but of superposed origin in its deep canyon. The Columbia River in its gorge through the Cascade Mountains of Oregon and Washington appears to be to-day our best example of a truly antecedent river. Let it be repeated that no antecedent rivers are found in the East because recent crustal upheavals there have not been unequal enough to provoke their development.

Dissected Plains in Intramont Basins

Although Green River can no longer be accepted as the type of an antecedent river, as Powell held it to be, it is an excellent example of a river that has cut down a deep canyon through an obstructing mountain mass—the Uinta Range—and at the same time dissected

[7] J. W. Powell, "Explorations of the Colorado River of the West," p. 163, Washington, 1875.

the detrital deposits of a large, down-warped, intramont basin up stream (north) from its canyon, for so the basin filling is described and pictured in Powell's report.[8] Another example of the same erosional procedure is found in the Bighorn Basin of Wyoming, an aggraded intramont depression measuring 110 by from twenty to thirty-five miles, where Bighorn River and its upper branches, after issuing from the hard-rock valleys of their mountainous head-waters, follow shallow and open valleys excavated in the weak deposits of a formerly smooth basin plain before their united waters enter the impassably narrow gorge of escape in the Bighorn Range on their way eastward to the Missouri-Mississippi system.[9] Hence, in these two cases, the Green and the Bighorn rivers have passed the preliminary, heterodox stage of mountain-valley and plain-channel existence and have entered well upon the more mature and orthodox stage of continuous but multiplex valley development.

Non-dissected Basin Plains

On the other hand, there are still several intramont basin plains in the Rocky Mountains which have not yet been dissected by their streams. The broad and meadow-like detrital plain which occupies the high-standing South Park Basin in the mountains of Colorado—almost uninhabitable because of its severe winter climate—is traversed contentedly enough at its own level by a head branch of South Platte River, which there seems to be quite unconscious of the great depth to which it will trench the plain when the outlet gorge through the hard-rock mountains comes to be more deeply incised than now. Similarly, the high-standing and smoothly aggraded basin plain known as San Luis "Valley" in southernmost Colorado possesses a surface, 150 by 50 miles in extent, that is for long distances dead level to the eye, although it really possesses a slope sufficient to cause a good current in its irrigating ditches.[10] Here the trunk river, the Upper Rio Grande, has like the South Platte not yet succeeded in trenching an outlet gorge, although it has a rapid fall below the southern barrier of the basin. Hence here, as around South Park, the valleys in the surrounding mountains all end as their wet-weather streams flow out upon the basin plain. These rivers are therefore still in the mountain-valley and plain-channel stage.

Another excellent example of such rivers is found on the non-dissected surface of a beautiful intramont basin plain known as Cache "Valley" in northern Utah and southern Idaho, less arid and more fully settled than the San Luis plain. Limited on the east by the broad highlands of the Bear River Mountains and on the west by the narrow and lowering northern extension of the long Wasatch Range, it measures about sixty miles north-south by ten or fifteen east-west. During the more humid climate of the Glacial period this basin was occupied to a depth of several hundred feet by a northeast arm of Lake Bonneville, the greater predecessor of Great Salt Lake; the high-level deltas and shore lines then formed are clearly seen to-day on the mountain flanks, and the fine sediments then laid down on the lake bottom still overspread much of the basin area. The high-level delta of Logan River, which enters the basin from a deep, canyon-like valley in the eastern highlands, serves as a picturesque site for the State Agricultural College, from which a fine view is enjoyed over the attractive city of Logan on the lower delta levels and far across the basin plain to its mountain rim. A map and a view of this delta are given in Gilbert's mono-

[8] P. 151, fig. 50.

[9] C. A. Fisher, "Geology and Water Resources of the Bighorn Basin, Wyo.," U. S. Geol. Surv. Prof. Paper 53, 1906.

[10] C. E. Siebenthal, "Geology and Ground Water of the San Luis Valley, Colo.," U. S. Geol. Surv. Water Supply Paper 240, 1910.

graph on Lake Bonneville.[11] Bear River, entering the basin through another gorge farther north in the eastern highlands, gathers to itself all the other inflowing streams but does not trench the basin plain. Its short outlet gorge, leading westward at a low sag in the Wasatch Range to the plain of Great Salt Lake, is followed by a railway line. A dam is there constructed for electric power. An electric railway, coming north from Salt Lake City and Ogden, enters the basin from the west over the lowering Wasatch crest south of the outlet gorge and offers its passengers a delightful prospect across the plain to the highlands on the east. A highway follows a similar course. Clearly, these three valleyless basin plains warrant the statement made above that various other basin plains in the Rocky Mountains, now more or less dissected by branching stream valleys, were also valleyless at an earlier stage of their evolution.

Aggraded Basin Plains Are Not Valleys

Let not the reader be deceived as to the real nature of the San Luis and Cache basin plains because they are called *valleys* by their occupants, for Western settlers have been undiscriminating in their use of physiographic terms. Many a broad plain, however smooth its surface, has been called a valley by its explorers and settlers if mountains are to be seen rising above its sides. Clearly the term *intermont* or *intramont plain* had never been learned in their schoolday study of geography. Even the single word *plain* would be a much better name than *valley* for these smooth surfaces. Furthermore, it seems to be because of the ill-advised appropriation of the term valley for flat intramont areas which should be called plains, that many an ordinary valley in the Western mountains is called a canyon, although it is much too well opened to deserve so emphatic a name.

[11] U. S. Geol. Surv., Monogr. I, pls. XXVI, XXVII.

Frémont, one of the earliest of our Western explorers to use this Spanish name, correctly noted that it signifies "a defile or gorge in a creek or river, where high rocks press in close, and make a narrow way, usually difficult and often impossible to pass"; but to-day all sorts of open and easily traversable valleys are called canyons by physiographically irresponsible Westerners. It must be admitted, however, that in the way of terminology geographers have been much less enterprising than their botanical confrères, for while botanists have developed an admirably complete nomenclature for the description of the varied forms of plants and have advanced the nomenclature with the advance of their science, geographers have, as a rule, tried to get along in the description of complicated land forms with such old words as they found, ready made, in popular use. So strong has been the prejudice in favor of this unscientific procedure that the few progressives who have occasionally ventured to coin a new word for the better description of a particular kind of topographic feature have been not infrequently censured by their more conservative associates as ill-advised innovators. But surely even these conservatives can not object to the use of so proper an old term as plain for plain areas, although it is not to be expected that Western farmers will cease calling their plains valleys.

The Great American Desert

We may now go beyond the enchained ranges of the Rocky Mountain system. No space can be given to the Plateau province which, with its nearly horizontal structure, occupies a large area around the one-and-only point where each of four states meets the other three in a square corner, and which exemplifies the development of true erosional valleys to a superlative degree. We must enter at once upon the desert plains and the isolated ranges of the Great Basin, so strikingly developed between the Wasatch Mountains of Utah and the Sierra Ne-

vada of California, and extending thence southeastward into Mexico. Here we shall find that not only does modern orogenic deformation increase in its abrupt range-and-trough irregularity of displacements, with the result of making the mountain valleys discontinuous, but that climatic aridity combines therewith to increase valley discontinuity by rendering most of the rivers discontinuous also. Hence here the contrast between the valleys of the East and the West reaches its climax.

This is the arid region which Frémont long ago called the Great American Desert; and although the name later became unfashionable among Western settlers and was "taken off the map," the desert is still there, except for relatively small irrigated districts. That early explorer traversed the Great Basin twice in 1843–44, and knew whereof he wrote: he records that the region was already then called a desert, and adds:

> From what I saw of it, sterility may be its prominent characteristic; but where there is so much water [as supplied by several inflowing rivers] there must be some oases. . . . The whole idea of such a desert . . . is a novelty in our country. . . . Interior basins, with their own systems of lakes and rivers, are common enough in Asia . . . but in America such things are new and strange, unknown and unsuspected, and discredited when related.[12]

Fault-block Mountain Ranges

All through this vast arid area, which includes the whole of Nevada, eastern California, western Utah and southwestern Arizona, orogenic forces appear to have acted during the geologically recent past in the way of, first, breaking profound fissures in an extensive land mass of moderate relief and thus dividing it into elongated blocks of earth-crust, trending about north-south, from ten to fifty or more miles in length and from one to ten or twenty miles in width; and second, raising or lowering, warping and tilting the blocks in most irregular fashion. Deep earth-crust fissures of this kind, on which displacements occur, are known to geologists as faults, and the displaced crustal masses are called fault blocks. The Basin Ranges may therefore, in so far as they are thus produced, be called fault-block ranges, but it must be understood that during and since block faulting, the uptilted masses have been more or less eroded, dissected and degraded, as will be further told below. It is not intended to imply that all the Basin Ranges are dissected fault blocks, although I believe that a majority of them are of that origin.

The fissures of displacement are often compound, comminuted fractures, somewhat as shown in Fig. 3, rather than smooth breaks, and faulting on them has probably taken place in many fits and starts of small movement, each accompanied by an earthquake, between intervals of quiescence that would be considered long from a human point of view, but which would be regarded as brief as the earth looks upon time. Recent crustal deformation in this region may, indeed, be said to be geologically active. The contrasts thus found between the tame epirogenic equability of crustal deformation in the Appalachian highland and the excited orogenic diversity of displacement in the Great Basin gives good geological warrant for speaking of the West as persistently "wild."

Like the earlier and much less extensive breaking and tilting of long crustal blocks in the Appalachian belt, after it had been folded and degraded, the breaking and tilting of the Great Basin blocks appear to be the work of secondary forces, acting superficially, in consequence of deep-seated deformation due to primary forces. And like the re-

[12] "Report of the Exploring Expedition to the Rocky Mountains . . ." Washington, 1845. See pp. 264, 265. This interesting report is printed in a manner highly suggestive of the scientific undevelopment of our national government at its time. The volume has neither table of contents nor index; and, in spite of its extremely unlike parts, every one of its 580 pages is headed: "Doc. no. 166."

cent, basin-making deformation in the Rocky Mountain belt, the fault-block dislocations in the Great Basin were preceded by a great compressional deformation of more primary character, the two periods of disturbance being separated by a long interval of erosion. That interval was, indeed, so long that the mountains produced by the earlier compressional deformation had been greatly reduced and in places obliterated by degradation before the second deformation, which involved fault-block jostling, gave rise to the mountain ranges of to-day.

The up-raised blocks were, as above noted, somewhat eroded even during their active up-rising and have been still more eroded since the up-rising ceased. They now form many of the Basin Ranges, while the less up-raised or actually depressed intermont blocks constitute the rock floors of many inter-range depressions, and are therefore the seat of deposition for the detritus outwashed from the valleys eroded in the range blocks. Thus the intermont troughs, as they are aggraded to fairly even surface, become intermont detrital plains. It is noteworthy that in the Rocky Mountain system the intramont basins are isolated among the interconnecting ranges, but in the Great Basin it is, as a rule, the ranges that are isolated, while the desert plains are interconnected around them. Most of the plains might therefore be called circummont; but some of them are only intermont or even intramont. The Rocky Mountains thus constitute a true mountain chain, in which the intramont basins are the spaces within the irregular links. The Italian Apennines are of a similar nature: one of their most typical intramont basins is that of Florence, drained by the middle Arno; its surface is smooth and undissected; another, also undissected, is that of the upper Tiber between Perugia and Assizi; a third, more beautiful than the other two because it is now well dissected, is that of the upper Arno, its main trench being known as the Valdarno.[18] On the other hand, the Basin Ranges of our West do not constitute a chain; a few of them are linked together, but most of them rise separately through the large meshes in the flat-lying and net-like interweave of aggraded desert plains.

Contrasts of Basin Ranges and Allegheny Ridges

No parallels to the Basin Ranges are to-day found in the Appalachians. True, the Allegheny Mountains, extending from Pennsylvania across Maryland, Virginia and Tennessee into Alabama, include many ridges that alternate with inter-ridge lower lands, as shown in Fig. 1, but these slender ridges are not local upheavals, like the Basin Ranges; they are erosional residuals, and they survive as ridges because the belts of steeply inclined and extra-resistant sandstones which control them have withstood erosion so much better than the broader intervening belts of weaker inclined strata, which are worn down in the lower lands. Moreover, the Allegheny ridges run in peculiar zigzag patterns, because they follow with precision the convolutions into which their controlling sandstones, along with the weaker formations, were crowded when the Appalachian belt was long ago compressed into gigantic folds. Furthermore, the inter-ridge lower lands are not aggraded troughs, but true although rather broad valleys of excavation. This may be made clear by referring again to Fig. 1, in which it is shown that the change from the nearly featureless plain of stage 1 to the alternating ridges and lowlands of stage 2 is a simple result of selective erosion, consequent upon broad epirogenic upheaval.

Examples of Fault-block Ranges

Orogenic diversity of deformation in the Great Basin, as exemplified in the

[18] W. M. D., "Der Valdarno, eine Darstellungsstudie," *Zeitschr. Ges. f. Erdk.*, Berlin, 1914.

fault-block ranges taken in connection with climatic aridity, is so largely responsible for the discontinuity of Western valleys in contrast to the prolonged continuity of Eastern valleys that a few examples of such ranges may be here adduced. A typical mountain-making fault block is found in the Warner Range of northeasternmost California, of which R. J. Russell has lately given an excellent description.[14] The range is part of a huge mass of heavy lava and ash beds, at least eight thousand feet in total thickness, which must have lain horizontal when first outpoured but which now, in the mountain range, are up-faulted so that they slant at a moderate angle to the west and present a great escarpment to the east. The range block measures about eighty-five miles in north-south length and from eight to twenty miles across. The western or back slope, where several minor faults occur with increasing strength northward, is moderately furrowed by consequent valleys. The eastern or fault face is sharply ravined and much battered back by weathering and washing. The present crest of the range, somewhat lowered by a rather strong retreat from the potential fault-block edge, still reaches altitudes of from 8,000 to nearly 10,000 feet; it was therefore high enough to have borne small glaciers in the Glacial period, traces of which are seen in several valley-head cirques. The eastern face descends to a great, aggraded, intermont plain, known as Surprise "Valley," which occupies a down-faulted trough: its surface altitude is somewhat under five thousand feet; wells show the depth of accumulated detritus to be eight hundred feet at least. The plain is bounded on the east, just across the Nevada line, by another fault-block range, which is tilted to the east and has its ravined fault-face to the west.

Two highly instructive ranges in the Humboldt Lake region of northwestern Nevada have been well described by Louderback,[15] whose account of them shed a flood of light on the fault-block problem. The main body of these mountains consists of ancient and compressionally deformed strata which, after erosional reduction to moderate or low relief, were unconformably overspread with beds of tuff and sheets of lava, lying level. The compound mass was then faulted in two blocks with eastward slant, the fault lines being unrelated to the deformed structures seen in the block faces, and the faulting apparently involving lateral extension instead of compression. The two ranges thus produced have been moderately eroded, but the lava sheets still cover the greater part of their back slopes. The physiographic value of these ranges lies in the convincing evidence that they furnish for the two-cycle sculpture of their rock mass; that is, of the almost complete destruction, during a long cycle of erosion, of the ancient and lofty mountains which must have been produced by the compressional deformation of their ancient strata, before the worn-down and then lava-shrouded mass was block-faulted into the present cycle of mountain existence. In no other way can the unconformable lava cover now seen on the back slopes of the two ranges be explained. A number of other ranges are known in various parts of the Great Basin which also have the worn-down rocks of their back slopes more or less lava covered and thus teach the same lesson. In the desert interior of southeastern California I have crossed a series of nine north-south blocks, large and small, all faulted apart and tilted, as

[14] R. J. Russell, ". . . The Warner Range . . .," *Univ. Calif. Bull. Geol.*, 17: 387–496, 1928.

[15] G. D. Louderback, "Basin Range Structure of the Humboldt Region," *Bull. Geol. Soc. Amer.*, 15: 289–346, 1904. Other important essays on the Basin Range problem by this author are: "Basin Range Structure in the Great Basin," *Univ. Calif. Bull. Geol.*, 14: 329–376, 1923; and "Period of Scarp Production in the Great Basin," *ibid.*, 15: 1–38, 1924.

proved by their "Louderbacks,"[16] and the three largest of these faults, slanting at angles of about 50°, clearly imply a horizontal, east-west extension in association with the faulting.

Potential and Actual Fault-block Ranges

Many of the Basin Ranges have, in consequence of long-continued erosion, suffered a much greater modification of their potential fault-block form—that is, of the form that they would have if upheaval had not provoked erosion—than the above-described Warner Range in northeastern California and several other louderbacked ranges. They are deeply dissected by many ramifying valleys, the erosion of which must have begun when upheaval was initiated and must have continued after it ceased. Their originally simple fault scarps are worn back almost or quite beyond recognition, their crests are much worn down and notched and their back slopes are so maturely carved that the form of their pre-upheaval surface is completely lost. The Peacock Range, a granitic mass in northwestern Arizona, is a good example of a maturely modified range, and there are scores of other ranges believed to be similarly modified; but however much modified they agree in having their valleys end as they open out upon the piedmont detrital fans of their wet-weather streams.

The Peacock Range is, however, of peculiar interest, because some of the declining spur ends of its back or eastern slope are overlapped with slanting beds of lava of small extent—little Louderbacks—which, inasmuch as they rest upon an evenly slanting surface of granite, testify very clearly to several matters of importance in the history of the range. First, before the lava beds were tilted, they and the smooth surface of granite on which they rest must have stood about level, and hence before the lava was poured out the massive granite must have constituted a rock plain. It must be here recalled that granite is a rock of underground origin; when seen at the earth's surface the cover of other rocks as well as more or less of its own upper part must have been removed by erosion; and in the course of such removal its surface must have been carved into mountainous form, as in the schematic background of Fig. 3, for only after passing through a mature stage of mountainous form could it have been reduced, in the senile stage of a long-undisturbed cycle of erosion, to a surface of low relief, as in the second section. Next, about the end of that long cycle of erosion but previous to the block-faulting, a volcanic eruption took place, covering at least part of the worn-down granite surface with an outpouring of lava, as imagined in the right half of the third section. Then, after the volcanic eruption, a pronounced eastward tilting of a large block of the worn-down, granitic lowland occurred, the potential form thus produced being represented in the fourth section.

The large up-tilted block was presumably limited on the west by a strong fault,

[16] A simple, perhaps too simple, summary of the later geological history of the Basin Ranges may be outlined as follows: A great series of rock formations, which may be called the King series as it was first studied out under the direction of Clarence King in the seventies, was severely deformed in mid-Mesozoic time. The resulting mountains, the King Mountains, were worn down during a long period of relative quiescence to a surface of moderate or low relief, which may be called the Powell surface as its existence was first inferred by Powell. This undulating lowland was broken into fault blocks, which may be named the Gilbert blocks as Gilbert first recognized their occurrence; and the blocks were diversely displaced, the higher ones becoming the Basin Ranges, while the lower ones, if low enough, were aggraded to intermont plains. Wherever the Powell surface, before its faulting, happened to be covered by a lava sheet in such a location that a Gilbert block carried part of the sheet on its rear slope, the block may, with apologies to the head of the department of geology at the University of California, be described as "louderbacked."

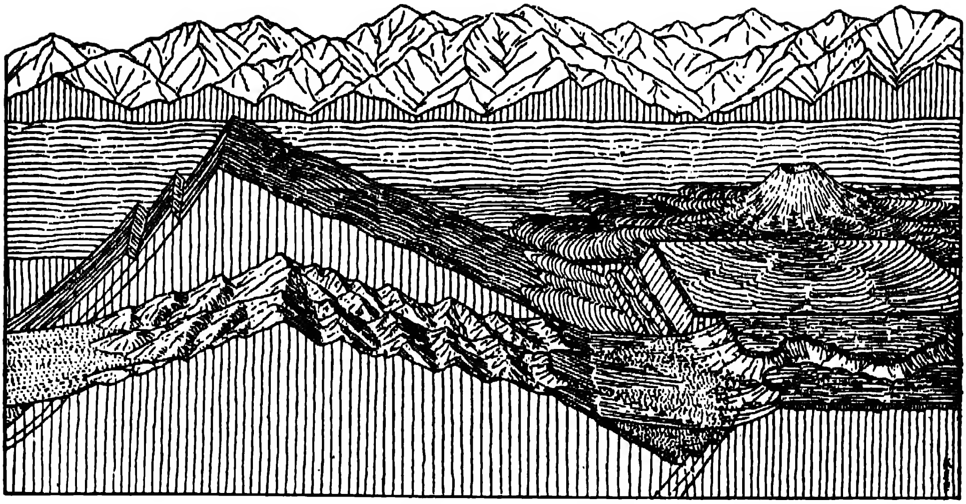


FIG. 3. FIVE-SECTION DIAGRAM, LOOKING NORTH, TO ILLUSTRATE THE EVOLUTION OF THE PEACOCK RANGE

IN NORTHWESTERN ARIZONA. BACKGROUND SECTION, A MATURELY DISSECTED MASS OF GRANITE. SECOND SECTION, THE SAME REDUCED TO A PENEPLAIN. THIRD SECTION, THE GRANITE PENEPLAIN PARTLY COVERED WITH LAVA SHEETS, POURED OUT FROM A VOLCANIC CONE. FOURTH SECTION, THE POTENTIAL (NON-ERODED) FORMS PRODUCED BY THE DISLOCATION OF THE PENEPLAIN AND ITS LAVA COVER. FOREGROUND SECTION, THE TILTED BLOCK IS MUCH WORN DOWN IN THE PEACOCK RANGE WITH LITTLE LOUDERBACKS AT ITS EASTERN BASE; THE EVENLY UPLIFTED, LAVA-COVERED TRUXTON MESA IS CUT THROUGH BY A CANYON.

inasmuch as a broad detrital plain now skirts the mountain range on that side, while at the same time a narrower lava-covered block next to the east was evenly uplifted, constituting the little Truxton mesa; and farther east still the much higher and vastly broader uplift of the great Arizona plateau, not included in Fig. 3, took place. Finally, the up-faulting must have occurred long enough ago for a rather strong recession of the fault scarp by which the broad plateau region on the east is limited, for the entrenchment of a canyon across the Truxton mesa block, in which a fine section of the undulating surface of the granite under the lava cover is exposed,[17] and for a great erosional reduction of the uptilted mass of the Peacock Range during and after the tilting, as in the foreground section of the figure. For not only is the western fault face of the range block maturely carved by many branching valleys, in consequence of which the inter-valley spur ends have retreated back of the fault line, but the eastern or back slope of the block has also been valley-scored, and so deeply that its ridge crests are now worn down decidedly below the potential back-slope surface, as indicated by the slant of the little Louderbacks. Moreover, the inferred volcanic cone, from the basal slopes of which the lava outpourings made their escape, must also have been much eroded; its location is not mani-

[17] In the "Guide-book to the Western United States," Part C, the Santa Fé route (U. S. Geol. Surv. Bull. 613, 1915), it is said that the Truxton lavas lie on "an exceedingly irregular surface of granite, filling up valleys and burying low peaks and ridges." In view of the low relief of this buried surface, it might be better described as "minutely uneven," thus leaving the stronger phrase, "exceedingly irregular," for the description of the much less reduced surface in the background block of Fig. 4.

fest, although thickening of the lava beds in the southern part of Truxton mesa, not shown in Fig. 3, suggests that it was thereabouts.

All this is so clear that it may be seen and understood from a passing car, for the scantiness of vegetation on the desert mountains lays bare their rock structure with a distinctness that is perpetually astonishing to a geologist brought up in a humid climate. The relation of underground structure to surface form, which has to be searched out in tree-covered regions, is here displayed almost at a glance; but it is of course always well to confirm the glance by a closer and more deliberate scrutiny. The visibility of rock structure in the desert has, indeed, strongly influenced the direction of scientific investigation there; for just as geologists became paleontologists in New York State, where the strata, overlapping southward, contain a rich store of fossils arranged as if on museum shelves; just as geologists became topographers in Pennsylvania where the heavier and less fossiliferous strata are folded in such a manner as to guide erosion in developing an intricate pattern of ridges and lower lands; just as geologists became petrographers in New England where a complex of crystalline rocks had to be unraveled; so in the arid West, the visible relation of underground structure to surface form gave so much meaning to the varied features of the landscape that geologists there became physiographers!

Discontinuous Valleys of the Great Southwest

The vast desert region of the Southwest, in which inter-trough ranges, carved out of up-faulted blocks, alternate with detrital plains built up in the down-faulted, inter-range troughs, is strongly characterized by the relatively small length of its true erosional valleys, for however sharply such valleys are excavated in the up-raised range-blocks, they end as a rule at the range margins and are not continued across the trough plains. Hence a resident in this region would not, like one whose home is in the Appalachians, regard valleys of erosion as essential accompaniments of streams. Here, as already noted, one finds the physiographic contrast between East and West most strongly developed. In the West, in consequence of marked inequalities of recent orogenic movements of the earth's crust coupled with climatic aridity, the valleys are markedly discontinuous; in the East the valleys are, in consequence of the extraordinary equability of recent epirogenic movements coupled with climatic humidity, long and of striking continuity. But these broad statements as to the absence of eroded valleys from the aggraded plains of the Great Basin are open to various qualifications, some of which will be pointed out below.

Detrital Deposits of Intermont Troughs

In the absence or sparseness of vegetation on the valley sides of desert mountains, weathered detritus is not detained there until it is disintegrated to fine texture, as is the case on forested slopes. When a heavy rain falls on a desert range, coarse as well as fine rock-waste is hurriedly washed down the slopes to a stream line, and is there even more hurriedly and in larger quantity swept along by the flooded stream and discharged in wild disorder upon its valleyless piedmont fan. The roaring rush of the turbid waters may be heard for a mile or more in the desert stillness; rock blocks of astonishing size are carried forth and left stranded at surprising distances from the valley mouth.

It must not, however, be inferred that the detritus now seen in an intermont trough plain has been carried from its source to its destination in single floods, for floods from mountain valleys often fail to flow so far as the trough mid-line.

Moreover, flood-causing rains fall not only over the mountains but on the plains also, and a plains flood gives a farther carry to detritus that fell short of destination in an earlier carry by a mountain flood. On the other hand, if the mountain streams in high flood flow far enough forward, they will join forces for a time and form a trunk river along the lowest line or physiographic axis of a trough plain, as defined by the meeting of fan-slopes from the mountains on either side. Yet the trunk river is likely soon to dwindle away, for down-stream from the area of the flood-causing rain its flow diminishes rapidly by soaking into the porous and thirsty detritus of the trough floor. Hence soon after the supply of rain water from passing thunder-clouds is drawn off the river disappears, leaving its braided channel dry; and then the head branches, if they are still able to flow at all, are left in betrunked discontinuity far up in the mountains. However, a surprisingly large store of in-soaked ground water long remains in the detrital trough filling, where it is available for recovery from wells of moderate depth by wind-, gas- or wire-power pumps. The growing city of Tucson in southeastern Arizona depends wholly on the pumped-up ground water of its intermont detrital basin.

It follows from the above account that the streams of the dry country are occasionally longer though usually shorter than their mountain valleys, also, that dry, gravel-bed channels on aggraded fans and plains are as characteristic of inter-range troughs as rock-walled valleys are of inter-trough ranges. Again, it follows that, although the aggraded troughs of the dry country are almost universally called "valleys" by their occupants, they are the very opposite of true, physiographic valleys; for not only is their broad surface the work of deposition rather than of erosion, but they often lack one of the most essential characteristics of true valleys, namely, a continuous descent along their lowest or plain-bottom line. This line, the physiographic axis of the trough plain as above defined, has not as a rule a continuous slope in one direction all along its length, as a normal valley has, but repeatedly rises over faint swells and sinks in shallow swales, the swells being generally determined by the accidental meeting of extra large fans from the opposite sides of the trough, while the swales result from a deficiency of in-filling; they do not stand in any necessary or close relation to original rock-bottom basins of the down-bent trough blocks. They are commonly the site of shallow saline lakes or of dead-level clay flats, from which the in-flowing water disappears chiefly by evaporation. The flats are commonly known by the Spanish name *playas*.[18]

[18] A good account of our Western playas has been written by I. C. Russell, in his essay on "Present and Extinct Lakes of Nevada," *Nat. Geogr. Monogr.*, 101–136, 1895.

(To be concluded)

BIOCHEMISTRY AND THE PROBLEMS OF ORGANIC EVOLUTION

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THE contributions which biochemistry can offer to the problems of organic evolution have, so far as the author is aware, never before been stressed.

The appearance of the various plants and animals on this earth has been explained in terms both of a progressive evolution and of a special creation. This paper was not written in an attempt to overthrow the views of those who believe in a special creation. They are entitled to their beliefs. It may well be that one person can fit certain facts into a certain belief or theory and another person can fit the same facts, just as logically to himself, into another set of beliefs or theories. As a scientist the author is interested not in proving or disproving any set of theories or beliefs, but in presenting for the reader's consideration certain interesting facts and allowing the reader to draw from those facts whatever conclusions he may desire.

To be more specific, that which is attempted is to point out the great harmony, from the biochemical standpoint, which exists in nature, and to permit the reader to draw his own conclusions as to the manner in which that harmony was brought about. An effort has been made to differentiate rather sharply between what is known in the way of scientific facts and what the author believes to be the scientific interpretation of those facts.

The term, biochemistry, is susceptible of two definitions. The first definition, because of the limitations of our present inadequate knowledge, must be regarded as tentative, eventually to be replaced by a more positive definition when scientific facts have accumulated to a point where final generalization may be made.

Therefore, for the present the definition of biochemistry may be stated as "a field of science devoted to the study of the natures and reactions of those compounds found in living matter and the rôle which these compounds play in the living organism," with the ultimate hope that this definition may be restated as "a field of science yielding an interpretation of the reactions of living organisms in terms of physics, chemistry and mathematics."

Life, from a mechanistic standpoint, may be looked upon as the resultant of a series of complex chemical reactions.

We are inclined, for purposes of convenience, to divide living organisms into the plant and animal kingdoms, but when we reduce our studies to single cells we find that many complexities have vanished and, in the last analysis, both the plant cell and the animal cell have much in common. We are inclined to think of life in terms of the response of the multicellular organisms, whereas the actions and reactions of the multicellular organism are only the expression of the integrated or average reactions of the cells which comprise that organism.

Death, from the standpoint of the multicellular organism, is only the failure of coordination between the cells comprising that organism. Many individual cells may remain alive and functional for hours or even days after the organism as a whole is pronounced to be dead. Death in a single cell is the failure of some chemical reaction which is essential to the maintenance of the equilibrium of the living protoplasm.

As we shall see, the chemistry of the plant cell is probably of a higher order and is more complex than is the chemistry of the animal cell.

The plants have two functions: (1) the transformation of radiant energy

into chemical reservoirs of energy for future generations, and (2), to a minor degree, the utilization of a part of this stored energy to furnish the driving force for the parent organism. The animal organisms, in most instances, lack the ability to accumulate radiant energy into a stored form but depend upon the plant for the energy which they need in their vital processes.

The plant may be looked upon as analogous to an automobile having both an ideally perfect storage battery and an electric lighting system. It takes energy from the dynamo (the sun) and stores it, at the same time utilizing a fraction of that energy for its own activities. The animal is essentially a flashlight, the bulb of which functions only because a source of electrical energy has been stored in a "dry cell" produced in another factory. When the dry cell is exhausted, the light no longer burns.

The animal kingdom is therefore saprophytic and entirely dependent upon the plant kingdom for its existence.

Granted then that plant and animal cells have much in common, both in structure of the cell (morphology) and in the biochemical reactions, a study of the processes going on in the plant cell involves, in the last analysis, more complex problems than does a study of the chemical processes characteristic of animal cells, for in the plant cell we must study not only the processes involving the utilization of energy but also those involving the more important fixation of energy.

The basic chemical reaction which makes possible life as we know it to-day may be written in chemical shorthand as

$$6\ CO_2 + 6\ H_2O + 677.2\ \text{Cal.} = C_6H_{12}O_6 + 6\ O_2$$
(photosynthesis),

i.e., six molecules of carbon dioxide plus six molecules of water plus 677.2 kilogram calories of radiant energy bring about the formation, in the plant cell in the presence of chlorophyll, of one molecule of sugar (glucose) and six molecules of oxygen. All the carbon in coal, all the carbon in peat, in petroleum, in our forests, in our foods and in our bodies is derived initially from this fundamental process which we call photosynthesis.

The second great fundamental equation of life is the reverse of the first, and may be written

$$C_6H_{12}O_6 + 6\ O_2 = 6\ CO_2 + 6\ H_2O + 677.2\ \text{Cal.}$$
(respiration),

i.e., one molecule of sugar (glucose) plus six molecules of oxygen yields six molecules of carbon dioxide, six molecules of water and 677.2 kilogram calories of heat energy in the process which we call respiration, and by this process of respiration the energy of the sunlight which was stored by the plant is made available to carry on the chemical reactions of the cells, both of plants and animals.

Man is a wonderfully efficient machine. In a day of hard work he requires about four thousand large calories of energy. This is the energy equivalent of approximately one pint of gasoline. No machine yet devised by man is as efficient a utilizer of energy as is man himself.

A consideration of the chemistry of living processes dates from comparatively recent times. Aristotle and the alchemists believed that water was transformed by living organisms into the body tissues. Van Helmont tested this theory about 1640 when he planted a willow tree weighing five pounds in a jar of dried and weighed soil. During a period of five years the tree grew to one hundred and sixty-nine pounds and three ounces (wood and leaves), being watered during the entire period only with rain water or distilled water. When, at the end of the experiment, the tree was removed and the soil was again dried and weighed, it was found to have lost only two ounces; therefore, the logical conclusion was drawn that water had been transmuted into wood and leaves. The only mistake Van Helmont made

was to ignore the traces of carbon dioxide in the air as a potential source of carbon.

While the two great equations of life already noted apply without exception to all the higher forms of the plant and animal kingdoms, nevertheless we have evidences of certain smaller and earlier biological worlds within our own, apparently inclusions and relics of an earlier past. Certain lower forms of living organisms (bacteria) do not utilize carbon compounds as a source of energy. Their energy relationships are possibly relics of an earlier day when there were no carbon compounds, back when life was just beginning upon the earth.

Thus, for example, certain of the "iron bacteria" derive their energy by the oxidation of ferrous bicarbonate, probably according to the following reaction:

$$4\ Fe(HCO_3)_2 + O_2 \rightarrow 2\ Fe_2O_3 + 8\ CO_2 + \text{energy}.$$

Most, if not all, of our "bog iron ore" deposits have been laid down in the earth's crust through this chemical reaction which characterizes the energy cycle of the iron bacteria. The enormous deposits of iron ore in the Cuyuna and Mesaba Ranges of Minnesota, estimated to have contained 4,200,000,000,000 tons of ore, have apparently all been laid down by this "iron bacteria" reaction. The ferric oxide formed by the oxidation remains within the cell of the bacterium and accumulates in a bed of iron ore as the bacteria die. Even at the present time in many places this process of iron accumulation is actively proceeding.

Other similar reactions involve the oxidation of hydrogen sulphide to sulphuric acid:

$$H_2S + 2\ O_2 \rightarrow H_2SO_4 + \text{energy};$$

the oxidation of ammonia to nitric acid:

$$NH_3 + 2\ O_2 \rightarrow HNO_3 + H_2O + \text{energy},$$

or even the oxidation of elemental sulphur to sulphuric acid:

$$2\ S + 3\ O_2 + 2\ H_2O \rightarrow 2\ H_2SO_4 + 283.6\ \text{Cal.}$$

It seems probable that the oxidation of sulphur to sulphuric acid and of ammonia to nitrous and nitric acids by bacteria in cavities in the rocks may have been responsible for the initiation of the formation of a true soil upon the earth. Thus, F. W. Clarke in his "Data of Geochemistry" states:

> Even forms of life so low as bacteria seem to exert a definite influence on the decomposition of rocks. A. Müntz has found the decayed rocks of Alpine summits, where no other life exists, swarming with the nitrifying ferment. The limestones and micaceous schists of the Pic du Midi, in the Pyrenees, and the decayed calcareous schists of the Faulhorn, in the Bernese Oberland, offer good examples of this kind. The organisms draw their nourishment from the nitrogen compounds brought down in snow and rain; they convert the ammonia into nitric acid and that, in turn, corrodes the calcareous portions of the rocks. The effect thus produced at any one point may be small, but in the aggregate they may become appreciable.

And Henry Fairfield Osborn, in "The Origin and Evolution of Life upon the Earth," adds:

> It is noteworthy that it is the nitrogen derived from waters and soils rather than from the atmosphere which plays the chief part in the life of these organisms; in a sense they represent an early stage in chemical evolution, since carbon is not their prime constituent, also adaptation to an earth-and-water environment rather than an atmospheric one.

We are inclined to emphasize the nitrogen-fixation processes which have been one of the recent contributions of chemistry to agriculture. Arrhenius, however, has calculated that the rainfall alone brings down to the earth 1,500,000,000 tons of nitrogen in the form of ammonia and nitric acid, this nitrogen being derived from volcanic gases, from silent electrical discharge through the atmosphere, from ammonia escaping from the soil and the nitric acid formed by the action of lightning. Nitrogen fixation in the soil by bacteria amounts on the average to about twenty-five pounds per acre per year, this being from four to six times the amount of nitrogen which is added to the soil by

the rainfall. Contrasted with this, the estimate of the world's chemical nitrogen-fixation industry for 1927 was 700,000 tons of nitrogen.

The bacterium *Thiobacillus thiooxidans,* which utilizes elemental sulphur as its source of energy, is of interest to the biologist, inasmuch as this bacterium can tolerate a higher concentration of actual acidity (hydrogen ions) than any other organism which has yet been found. *Thiobacillus thiooxidans* will produce sulphuric acid by the oxidation of elemental sulphur in as high a concentration as 10.2 per cent. sulphuric acid, and the organism will still remain viable.

Such forms of life as those noted above may have persisted for ages and then somehow—somewhere—the wonderful compound which we know as chlorophyll was "invented." This is the compound which gives the green color to the higher plants of to-day. Prior to its "invention," the sulphur bacteria were limited to that area where deposits of elementary sulphur exist, the iron bacteria to the slowly flowing waters containing soluble iron salts, the oxidizers of ammonia to the ammonia brought down by the rain from the heavens, but now—the chlorophyll-containing organisms could for the first time utilize the energy radiated from the sun and sent out through space, and in the presence of carbon dioxide and water, which were ever abundant, could store the radiant energy for future utilization. The power station of life had been constructed. No longer was life on the earth limited to shallow pools in the rock surfaces, to the warm waters of sluggish streams and to the tidal pools of the seashore. Plant life now could distribute itself over the entire earth, limited only by temperature and moisture conditions. In the atmosphere there was an inexhaustible supply of carbon dioxide and in the sun a never-failing source of radiant energy.

The "invention" of chlorophyll made possible the life of the higher plants and animals.

Modern biochemistry has developed almost entirely since 1840. The researches of De Saussure, of Wöhler, of Liebig and of Lawes and Gilbert paved the way for the modern structure which admittedly is still in its foundation stages.

The chemist knows to-day of ninety-two chemical elements. Until recently we have believed that only ten of these were essential for plant growth. Recent work indicates that a number of others are essential but are required in only extremely small amounts. The ten elements generally accepted as essential are carbon, hydrogen, oxygen, phosphorus, potassium, nitrogen, sulphur, calcium, iron and magnesium. Of these, only one, oxygen, can in general be directly utilized as such by both plants and animals. Both plants and animals can utilize directly the inorganic compounds of hydrogen (in the form of water), phosphorus (in the form of phosphates), potassium, calcium, magnesium and iron (in the form of their inorganic salts). In addition to the ten principal elements that are listed for plants, the animal organism (and probably also most plants) requires adequate supplies of sodium, chlorine, iodine, copper, manganese, etc. These, however, can be utilized when present in inorganic forms. But only plants can utilize the inorganic forms of carbon (in the form of carbon dioxide), nitrogen (in the form of ammonia or nitrates) and sulphur (in the form of sulphates). These three elements make up approximately 60 per cent. of the dry matter of the human body, and all that 60 per cent. has, in the last analysis, been derived directly or indirectly from plants.

The energy for growth and maintenance for both plants and animals and the energy for locomotion of animals are derived from the energy originally

emitted by the sun and stored in plants in the form of carbohydrates (sugars) and fats. Both the plant and the animal can transform sugars to fats or fats to sugars, but only the plant can form either fats or sugars from the simpler inorganic compounds, carbon dioxide and water. Since, however, fats may be formed from carbohydrates or carbohydrates may be formed from fats in the animal body, we, as organisms, are not dependent upon the plant kingdom for the specific fats or the specific sugars which we need in our vital processes; *i.e.*, given an abundant supply of carbohydrates or an abundant supply of fats, the animal organism can apparently transform all or part of that supply into the varied sugars or fats required in its vital processes. Recent investigations, it is true, point to the possibility that there may be certain exceptions to this broad general statement. Thus, for example, the researches of Burr at the University of Minnesota appear to indicate that adequate growth and maintenance, at least for the white rat, are conditioned upon the presence of a minimum amount of certain of the fats in the diet.

Granted, then, that the transformation of fats to carbohydrates and carbohydrates to fats is possible, what about the great harmony in nature that we noted in regard to both the biochemistry of plants and of animals?

This may be illustrated as follows. There are sixteen possible so-called aldo-sugars of the general formula $C_6H_{12}O_6$. Fifteen of the possible sixteen have been artificially built up in the chemical laboratory. Only three (glucose, mannose and galactose) of the possible sixteen occur in nature either in plants or animals. Only these three of all the sixteen can be utilized as sources of energy by either plants or animals. Mannose never occurs, so far as we are aware, in animals except as a constituent of egg albumin. Galactose occurs universally in the mammals as a constituent of the sugar of milk and as a constituent of nervous tissue. In animals it is formed from glucose, but the seat of this transformation appears to be wholly in the mammary gland. We have not yet succeeded in the laboratory in effecting the transformation of glucose to galactose, although it takes place readily in the mammary gland. Glucose is the universal form in which the carbohydrates are utilized as sources of energy, and glucose is apparently the primary sugar formed from carbon dioxide and water by the process of photosynthesis in the green leaves of the plant.

When we turn to the fats, we find that only those fatty acids which contain an even number of carbon atoms occur in nature, and no animal so far investigated can utilize as a source of energy any of the fats which have been built up in the laboratory, the fatty acids of which contain an odd number of carbon atoms. Again an illustration of the harmony of biochemical processes in plants and animals!

But it is in the proteins that biochemical harmony and biological specificity are most strikingly illustrated. The proteins (egg white, lean meat, etc.) are composed of the so-called "amino acids," and up to the present approximately thirty of these amino acids have been isolated from proteins and have been studied. All these amino acids can be synthesized (built up) by plants from the inorganic forms of carbon dioxide, nitrates and water. Only one can be synthesized by animal organisms. This one, glycine, is the simplest of all the amino acids. It is highly improbable that it can be formed in the animal body by a building-up process similar to that which takes place in the plant cells, and it appears much more probable that it is formed by the partial breaking down of other and more complex amino acids.

If, then, we are to concede that animals are absolutely dependent upon plants for the amino acids which are

the building-stones which they utilize to form their body tissues, we must admit that plants represent a more primitive and an earlier, as well as a more efficient, form of life than animals, including man—that plants and plant life must have reached a high stage of development before animal life was possible.

To be sure, unless we are wholly vegetarians, a considerable portion of the amino acids in our body-tissue proteins may have been derived indirectly from plants through intermediate animals, the flesh of which we utilize as food, but they came to us unchanged from the original plant source! The bricks which were built into the original structure were incorporated into a new structure when the first was torn down, and when the second structure was torn down those same bricks unchanged were again incorporated into a third building. It is a new building of different architecture but one in which the old bricks still form the framework.

The dependence of the animal kingdom upon the plant kingdom is so absolute that if the mixture of amino acids in our food is lacking in any one amino acid of the proper chemical configuration to fit into the vital protein which the cell is building up, then the building-up process is blocked and the death of the animal organism inevitably ensues.

The artist can complete a perfect mosaic only when the artisan has supplied all the intricate pieces of the varicolored enamels. The animal body can build its proteins only when the plant kingdom has provided the varied amino acids. And this knowledge of biochemistry all dates since 1900!

The old theory of Liebig that protein is protein and a given minimum of protein in the diet would care for the protein needs of the animal body has been replaced by the statement that a protein which is eaten must be adequate in its content of amino acids. If the body needs a "Peter-Piper-picked-a-peck-of-pickled-peppers" protein, adequate nutrition will not ensue if a "Theophilus-Thistle-the-successful-thistle-sifter" protein is fed.

Aside from the dependence of the animal kingdom upon the plant kingdom in the matter of amino acids, the study of the proteins has shown other exceedingly striking indications of the unanimity of vital processes. The entire science of immunology may be regarded as a special field of biochemistry, a biochemistry where the animal is used as a test reagent. If a small amount of protein, as small an amount as one ten-millionth of a gram of egg white, is injected into the blood stream of a guinea-pig and then after twelve to fifteen days a second injection of a slightly larger quantity of the same protein is made, the guinea-pig will die in a convulsive spasm. Only egg white from the same species of bird used in the initial injection will produce this striking effect. The phenomenon is known as an anaphylaxis and the reaction as an anaphylactic shock. The initial dosage is referred to as a "sensitizing dosage"; the final dosage as the "intoxicating dosage." The phenomena of hay fever, some eczemas and many cases of "colic" in infants are more or less mild evidence of anaphylaxis. If some protein other than egg white had been injected the second time, there would have been no detectable reaction. The protein used for the intoxicating dosage will produce a shock only when it has the same chemical composition and chemical configuration as the protein used for sensitization. Our chemical methods of protein research are far too crude to distinguish slight differences in chemical configuration among many proteins, but using the immunological reactions of anaphylaxis, etc., it is possible to study biochemical and biological relationships which may exist between the proteins of various species and

genera of animals or plants, and thus trace (perhaps) degrees of phylogenetic relationship.

Now, what do such studies tell us? First, all mammals have at least one thing in common—the young are nourished with milk and the milk of all mammals contains a unique protein, casein. Casein occurs nowhere else in the products of living organisms than in the milk of mammals. Immunological studies tell us that the casein of the milk of all mammals is essentially identical in chemical composition and chemical constitution. The milk of the mouse, the milk of the whale and human milk contain the same protein, and the casein from these three sources can be used interchangeably in so far as the immunological reactions are concerned.

Second, the egg yolk of birds, fishes and reptiles contains another protein, more or less similar to casein, which we call vitellin. And here again, the vitellin from the yolk of turtle eggs, from fish eggs and from the various birds, including those which man has domesticated, are essentially indistinguishable from each other, in so far as immunological reactions or chemical analyses are concerned. Either nature followed exactly the same path in designing the casein molecules in each species of mammals and vitellin molecules in each species of birds, fishes and reptiles, or else a biological, as well as a biochemical, relationship exists among the various members of the orders of the mammals and among the various members of the orders of the birds, the fishes and the reptiles.

The reader is free to select whichever interpretation appeals to him as the more probable, but let us not consider the possibility that such a condition could have arisen by chance. That is entirely out of the question. For example, an individual protein, such as casein, is built up by the uniting together of probably hundreds of individual molecules of amino acids. Suppose, however, there were only twenty amino acids, all different, in a simple protein molecule. How many distinct "proteins" would be possible, each having the same chemical formula, each having the same amino-acid content, but each a different "protein" because of a different arrangement of the amino acids within the molecular structure? It would be the same old mathematical problem of in how many ways can you arrange twenty different books upon a shelf, and the answer is factorial twenty ($|\underline{20}$) or the enormous number of 2,432,849,185,428,480,000 different arrangements.

The biological reactions of the proteins enable us to differentiate rather sharply, in most instances, between those proteins which are characteristic of one species and those which are foreign to that species, and it is upon these observations that the entire modern structure of immunology has been built. Some workers point out that the species specificity which is demanded by the modern theories of immunology and which is shown in immunological reactions is almost infinite and therefore surprising. Considering the infinite possibilities of the linkages of amino acids in proteins, it is much more surprising that nature should ever synthesize twice in succession proteins which are even remotely alike.

Perhaps no more striking illustration of the exactness with which vital reactions are regulated in the living protoplasm can be given than the fact that, through untold generations, a given organism reproduces the same structural configurations in the proteins which characterize that organism. The fact that each species has a different set of proteins is not the surprising thing. The surprising thing is that nature is able to control the synthesis of proteins within a single species, so that the same protein is synthesized by all members of the species.

Further examples of the chemical and

immunological identity of proteins are found in wheat and its near relatives, spelt, emmer, durum and einkorn. The hereditary factors of organisms appear to reside in certain structures called chromosomes which are present in the cell nuclei. Einkorn has seven chromosomes; emmer and durum, fourteen chromosomes, and spelt and common wheat, twenty-one chromosomes. Students of plant genetics are fairly well agreed that durum and emmer arose by a doubling of the chromosome number of einkorn and that a tripling of the chromosome number gave rise to spelt and the common wheats—that einkorn represents an early stage in the progressive development of the wheat. A few years ago we investigated certain of the proteins of these grains and found that the protein which was present in the largest amount in the seeds was identical so far as chemical, physical and immunological tests could ascertain. This observation added one more link to the chain whereby the close family relationship of this group was established.

At the same time we investigated the protein of the seeds of corn, kaffir, sorghum and teosinte (*Euchlaena mexicana*, a wild grass of Mexico which had been suggested as the possible progenitor of maize). Here, again, there was found among the proteins of these seeds a close chemical, physical and immunological relationship. However, there was no immunological relationship between the proteins of the "wheat group" and those of the "corn group."

The blood serum proteins of closely related animals show more or less immunological identity, the intensity of reaction being more or less directly proportional to the closeness of relationship. Immunological tests are the basis, in criminal cases, for the identification of blood as to whether of human or of animal origin. Nuttall, in England, studied more than nine hundred species of animals, making more than sixteen thousand immunological tests, and found that the Primates were the only group of animals the blood sera of which contained proteins which showed relationships with the proteins of the human blood. A summary of his data is shown in Table I.

TABLE I

SHOWING THE INTENSITY OF THE PRECIPITIN REACTION BETWEEN THE SERUM OF AN ANIMAL IMMUNIZED AGAINST HUMAN BLOOD PROTEINS AND EQUIVALENT AMOUNTS OF BLOOD SERA FROM VARIOUS ORDERS OF PRIMATES

Blood serum from	Number of individuals tested	Intensity* of precipitin reaction
Human	34	100
Simiidae (Anthropoids)	8 (3 species)	100
Cercopithecidae (Common monkeys of the old world)	36	92
Cebidae (Capuchins and spider monkeys of the new world)	13	78
Hapalidae (Marmosets)	4	50
Lemuridae (Lemurs)	2	0

* 100 indicates a reaction essentially identical in intensity with that of the original serum used for immunizing.

Nuttall was unable to distinguish either a qualitative or a quantitative difference between the blood sera of man and those of the three species of the anthropoids. Again this may be a coincidence or it may indicate a close biological relationship.

Turning to another phase of biochemistry, let us consider the vitamin problem. Within the last fifteen years the importance of vitamins in the diet has been stressed. Here, again, plants are supreme! Man needs vitamin A for growth and well-being; vitamin B as a defense against beriberi and other nervous disorders; vitamin C as a defense against scurvy; vitamin D as a protector against rickets and to aid in calcification of the bones and teeth; vitamin E has not been proved essential for man but is required for certain animals in

the processes of reproduction; absence of vitamin G leads to the disease pellagra. All these vitamins can be formed by the plant cell. Man can, with certainty, form adequate amounts of only vitamin D, the antirachitic vitamin, and then only when ample exposure of the skin to ultra-violet radiation is provided. The rat can synthesize vitamin C, the antiscorbutic vitamin, so that in that respect at least the rat is superior to man; but in most instances, man, together with many of the other mammals, is dependent upon plant sources for his vitamin supply. The fact that most animals undergo similar reactions when deprived of some particular vitamin speaks strongly for similar biochemical mechanisms as governing the vital processes of the entire group.

One important group of biochemical compounds appears, with our present knowledge, to be limited almost wholly to the animal kingdom. It may be that the presence of compounds of this group is really the important distinction which separates the animals, and especially the higher group of the mammals, from the lower forms of life and especially from the plant kingdom. The group referred to is known as the hormones. Apparently the special functions and greater differentiation of the tissues and organs present in the higher forms of animal life have required specific chemical regulators to be present, and thus the hormones came into being. There are, however, suggestions that certain of these hormones may have certain analogues in the plant kingdom.

Typical of the hormones is thyroxine, the iodine-containing compound of the thyroid gland. Thyroxine may be regarded as a regulator of the metabolism of the body. The lack of it causes goiter, cretinism, mental inadequacy and idiocy; an excess of it causes hyperthyroidism and the actual burning up of the tissues of the body during the life of the individual. It is in order to maintain a proper supply of iodine for the formation of thyroxine in the thyroid gland that "iodized salt" is used on the tables of to-day. The amount of iodine in the normal thyroid probably lies between 0.1 and 0.5 grain.

Another hormone is epinephrine, secreted by the suprenal glands and thought to be responsible for the maintenance of blood pressure. It possibly also is responsible when secreted in excess for violent emotions and the reactions which accompany anger. It has been estimated that there is normally not more than 0.015 grain of epinephrine in the body at any one time, and an injection of three one-hundred-thousandths of a grain will produce a pronounced physiological effect.

Another hormone is insulin, which is secreted by a group of cells in the pancreas gland and which is required so that the body can completely burn the sugars as a source of energy. Lack of insulin brings on the characteristic symptoms of diabetes.

And so one might enumerate a number of other less well-known but fairly well-characterized hormones which control or regulate some important function of the human body. The point which it is wished to emphasize, however, is not that such compounds exist but that these same compounds likewise exist in other animals than man and in these animals perform essentially the same function that they perform in man. In hormone therapy we utilize desiccated thyroid of the sheep to supplement a deficient supply of thyroxine from our own thyroid glands; we use the insulin prepared from the pancreas of various animals—it can even be obtained from organs of the fish; and the epinephrine of our suprarenal glands is identical with a compound present in the "toxin" secreted by the skin of the tropical toad, sometimes used as a spear or arrow

poison and long ago prescribed by Pliny as a remedy for certain diseases. Dried toadskin, in spite of the fact that we laughed a few years ago at the foolishness of such a prescription, is in fact a very potent drug!

Man, from the standpoint of hormone relationships and hormone functions, is an integral part of the animal kingdom. There is more order than chaos in the biochemical interrelationships.

One more illustration in the realm of biochemistry will suffice. The enormous importance of the "invention" of chlorophyll, the green pigment of plants, has already been indicated, since by this "invention" the energy of sunlight could be fixed and made available to the higher forms of life, including man. No pigment, no compound, can ever exceed in biological importance chlorophyll itself.

But possibly ages after chlorophyll was first formed another pigment was synthesized, second only to chlorophyll in importance. Chlorophyll is a plant product, apparently exclusively a plant product. The new pigment belongs to the animal kingdom, hemoglobin, the red pigment of the blood!—the pigment which permitted animal life to develop into large multicellular organisms of complicated structure and function and to leave an aquatic environment for a terrestrial existence. The respiratory processes of the mammals of to-day are intimately associated with the red pigment, hemoglobin, of the blood stream.

Is there then any biochemical relationship between the most important pigment of the plant world and that of the animal kingdom? Recent researches have shown that in many respects they are almost identical! The complex central nucleus of the chlorophyll molecule is to all intents and purposes identical with the complex central nucleus of hemoglobin. In the plant the metal associated with the chlorophyll nucleus is magnesium; in the hemoglobin of animals it is iron. In the plants the nucleus has associated with it phytol, a complex, much-branched member of the group of higher alcohols; in the animal hemoglobin this residue is a protein, but, by and large, there is a remarkable similarity in the essential biochemical structure of chlorophyll and of hemoglobin.

The question as to how such a similarity came about is of interest. We can, of course, only speculate. There are, however, some suggestions, perhaps relics of an intermediate stage.

Certain animals do not possess hemoglobin. Their blood is not red but colorless or pale blue. In this group we find the Crustaceae, the lobster, the oyster, the crab. They possess not hemoglobin but an analogous compound, hemocyanin, containing not iron but copper. Still others, such as the tropical mollusk *Pinna squamosa,* possess neither hemoglobin nor hemocyanin, but instead their blood pigment is pinnaglobin in which the iron or copper is replaced by manganese.

Unfortunately, hemocyanin and pinnaglobin have been too little investigated to permit one to say how closely the structures of these compounds are related to chlorophyll on the one hand and to hemoglobin on the other. That is a problem for the future. But if one were permitted to speculate, it might perhaps be logical to think as follows.

The animal organism is dependent upon plant sources for the formation of many complicated chemical compounds. No chemical compound comparable to phytol, the complex higher alcohol of chlorophyll, has been found to be formed by animals, but the animal can form proteins, once given the animo acids from plant sources, so the phytol of chlorophyll was replaced by a grouping which the animal could synthesize, thus making the animal independent of the

plant for that particular grouping and allowing the animal to modify that grouping to suit its own special needs. Then the magnesium is not an oxygen carrier, but copper, manganese and iron may serve in that capacity, so somehow—somewhere—a new pigment came into being, chlorophyll modified in that a protein replaced phytol and copper or manganese replaced magnesium, and a respiratory pigment suitable for circulation in the blood stream was the result! Multicellular and multiorganed animal life became a possibility! But a constant supply of either copper or manganese can be assured only in a uniform and fairly constant environment. The ocean provided this, and even to-day the animals possessing respiratory pigments containing copper and manganese are limited to an aquatic life.

Later, far later probably as a geologist counts time, some animal "invented" a modified respiratory pigment in which iron replaced the copper or manganese, and the first hemoglobin was formed! Now for the first time was there a highly efficient respiratory pigment; iron exists in considerable amounts in all the waters and all the soils; it is present in appreciable amounts in all environments, and the new pigment was so efficient as an oxygen carrier that, when the proper anatomical organs were developed, a terrestrial existence of the larger animals became possible.

This reasoning is admittedly a hypothesis. It is presented as a possible romance of life. It may well form a basis for future investigations. Suffice it to add that even in the plant kingdom there is some obscure but still definite relationship between chlorophyll and iron, for while chlorophyll contains no iron, nevertheless chlorophyll can not be formed by the plant unless soluble iron salts are available in the soil. Within the last two or three years researches have shown that in all probability a similar relic of the earlier days still persists in the vital processes of the higher forms of animal life, since it appears that hemoglobin formation is impaired when all traces of copper or manganese (or both) are absent from the diet.

And so one might continue almost indefinitely. It might be pointed out that it is generally agreed that life arose in the warm, tropical seas, and that man, and in fact almost all the land animals, still live potentially in the ocean, for the blood which bathes every cell of our bodies is a salt solution containing the various chemical elements in almost the exact proportions, relative to one another, that are present in sea water. A slight changing in the relative proportions of these inorganic ingredients in our blood produces pronounced physiological effects. One might point out that the mechanism of respiration is common to all plant and animal cells and that man is no exception. But enough has been accomplished if it has been demonstrated that there is more order than chaos in the biochemical interrelationships throughout the plant and animal kingdoms and that biochemistry, as an independent science, has much to offer toward the solution of the problems of organic development. A marvelous harmony pervades throughout the biochemical processes which characterize vital phenomena. It is left to the reader to decide as to how that remarkable harmony came to be.

THE ARTIFICIAL PRODUCTION OF NEOPLASMS

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THE first thing to do is to define, if possible, what a neoplasm is. Strange as it may seem, this is not easy. The nearest approach is the text between the covers of a large monograph on tumors. Even this is inadequate because there are so many things still uncertain; a significant fact is that the detailed biology of tumors is either in dispute or is practically *terra incognita*. Hence no matter what definition of a neoplasm is adopted, it will be lacking in essentials.

But we must start somewhere, and so let us say that a neoplasm is a new growth of tissue, imitating, more or less, some normal tissue, growing for no obvious reason and to no definite termination, with no respect for other tissues; it is apparently outside of the control of the rest of the organism; it is without function, at least, without useful function, and if not removed completely it recurs and keeps on growing.

From the point of view of embryological derivation, most tumors consist of only one kind of tissue; exceptionally, they may contain derivatives of two or all three germinal layers and then are called mixed tumors or teratomas or embryomas, etc.

Now all new growths are neoplasms in a loose sense of the word. For instance, the hyperplasias are new growths. When the uterus enlarges to take care of the growing fetus, new muscle fibers are produced. The breasts of human and other mammalian females exhibit new growths alternately of glandular tissue and connective tissue during each menstrual cycle. Pregnancy initiates an enormous new growth here. When the normal exit of a hollow muscular organ is obstructed, such as the bladder by an enlarged prostate, or the pyloric opening by an ulcer or adhesions, the reaction includes new growth of muscle fibers. In the same class are the artificial growths produced in the uterus. Leo Loeb in 1907 first obtained a decidua-like neoplasm by irritating in various ways the endometrium of guinea-pigs. Quite recently, by the injection of different ovarian extracts, growths of the uterus and breast have been produced.

But these are not the kind of new growths ordinarily included in the term "neoplasm" by pathologists. In the first place, they are physiological, *i.e.*, they serve a purpose. Some attempt a sort of support to a physiological function which is being threatened with destruction. Their growth is limited to adequacy. They are under the control of another part or parts of the organism. In the second place, these growths stop when the demand ceases and then regress. The newly formed tissue disappears, *e.g.*, after birth, the uterus undergoes involution. The growth does not keep on, it is not autonomous and it respects other parts.

Another kind of new growth which pathologists have always sharply differentiated from tumors, but one which is closer to them than the physiological growths, is new growth caused by inflammation. Searching for a tangible difference, the best is probably that they are protective. Inflammation is a reaction used by the organism to ward off, or otherwise render deleterious influences less harmful. Anatomically, the new cells in an acute inflammation are easily differentiated from those of a tumor.

The cells which accumulate as a result of an inflammatory process are polymorphonuclear leucocytes, plasma cells, monocytes, etc., or blood cells. They do not constitute an organized tissue, since they are free and independent entities capable of wandering from place to place. Tumors, on the other hand, are tissues having mass structural qualities. A very important difference is that the cells of inflammation can not reproduce themselves while neoplastic cells are able to do so. Further, the new growths of inflammation stop and disappear when the causes are removed.

When the chronic inflammations, however, are considered, we find ourselves approaching nearer to some of the tumors. The important addition here to the accumulation of wandering cells is the active proliferation of connective tissue and the production of many new cells. This growth is capable of making considerable progress. But once again, when the cause of the proliferation is removed (such as a focus of infection), the proliferation ceases, the new connective tissue regresses, seldom completely, however, and a scar remains. Irritation, then, especially if long continued and of mild degree, produces a new growth.

Some very important questions arise. Do these new growths ever continue, even when the cause is removed? Do the new cells ever become autonomous in their multiplication and keep right on growing whether the cause is removed or not? If so, is this because the original irritation continues long enough, or is it finally changed qualitatively? Or is it because an unlimited proliferative force is developed within the cells? Or are all these and possibly other causes operating?

The keloid is an interesting example for scrutiny. When the skin is injured, it ordinarily repairs the wound to a fine scar. But in some cases this scar steps over the boundaries and produces a huge, heavy mass of fibrous tissue spreading far beyond the limits of the original injury. Ordinarily when repeated cutting is made, the succeeding scars will be but little larger than the first if the surgery is done skilfully. With keloids, on the other hand, no matter how carefully they are removed, the recurrences are larger and larger, until what was originally a wound, say a cut in the skin a centimeter in length, is replaced by a neoplasm of much greater dimensions. Here is a clear example of a reparative mechanism stepping over the mark and becoming what the definition says is a true neoplasm. Now keloids are exceptional. Yet they can be and are produced artificially. It is well known that certain African tribes deliberately produce keloids of various symbolic designs by roughly cutting themselves in the face, arms, chest, etc. This artificial production is probably largely limited to the Negroes for biological reasons which we do not yet understand.

The ordinary keloid stops growing at some time or another, but once in a while one of them simply will not stop, but proliferates on and on, until it finally kills its host and itself with it. Small particles are even carried to distant parts in the lymph and blood streams to produce secondary growths in other tissues and organs. It thus becomes a wildly growing connective tissue tumor which is called a sarcoma. A potentially fruitful line of investigation would be to see if there is any biological correlation between this type of neoplasm and the phenomenon of regeneration so common among lower forms.

Certain special forms of inflammation called the "infectious granulomas" are a step nearer the tumors. As their name implies, they are reactions to the presence of special micro-organisms, consisting of overgrowths of cells, chiefly endothelial, lymphocytes and fibroblasts. They are a step closer to neoplasms be-

cause the overgrowths are much greater in degree than those in simple chronic inflammations. The reaction growths to tuberculosis, syphilis and Hodgkin's disease are examples. Now the proliferations in all of them have been known at times to exceed all reasonable bounds, which means greater than protective and reparative needs seem to warrant.

We have seen so far, then, that there are physiological growths, and inflammatory, *i.e.*, protective and reparative, growths. Now while I have said that the latter occasionally overstep the boundaries and become true tumors, I have been very careful not to say this of the physiological ones. Although rigid experimental proof is lacking, the possibility must be considered. For example, the normal breast is never quiet but is always growing and receding, stimulated to the utmost growth, of course, by pregnancy, but more continuously by oestrus.

When impregnation occurs, the epithelial cells begin to multiply and produce more and more new glands, while the connective tissue gradually disappears. At full lactation, the breast consists of little else than glands, with a light supporting framework of connective tissue, vessels and nerves. When lactation is interrupted, the reverse occurs; the glands disappear and the connective tissue grows until the organ is restored to somewhat its former structure. The same changes occur at every menstrual period; though these are less in degree, they are repeated periodically over long intervals. Thus there is a constant, reciprocal, synchronized growth and regression of connective tissue and epithelium. This growth is physiological.

Now not infrequently there is found a very small, a beginning, cancer in a breast unaccompanied by inflammation or other changes. When the breast is from a woman in the menstrual age, and she states that her breasts always swell, become larger and tender just before menstruation, can it be assumed that the cancer is composed of epithelial cells which have been overstimulated to proliferation by the menstrual influence and thus have been started on an autonomous existence?

May this not be a physiological growth overstepping the boundaries? My own opinion is that it is, although I know of no direct experimental proof. Good negative evidence is provided by the studies of Leo Loeb. He found in mice that removal of the ovaries, which takes away the source of the periodic stimulus of growth of the epithelium of the breast, also reduces markedly the incidence of breast cancer.

When inflammatory growths are considered, clean-cut experimental evidence is at hand.

Clinical observation has shown that a neoplasm, a cancer, often begins at a point where there has been chronic irritation. For example, cancer develops in the cheek at the site where a jagged tooth continually tears the mucous membrane; cancer develops in the lip where a hot clay-pipe rests for years; cancer develops in the skin at the site, even when healed for years, of a former tuberculous abscess; cancer develops at the edges of the scar of an old burn, or where X-ray treatment was previously applied.

Experimentalists, taking advantage of these facts, have planned accordingly. Warts of fibrous and epithelial cells have been produced on rabbits' lips by repeated scraping of the healing area. Tumor-like growths have been deliberately produced by X-ray, etc.

Another clinical observation stimulated a large amount of work in what might be called the "chemical method" of producing overgrowths. It was known for many years that chimney-sweeps were peculiarly susceptible to the development of cancers of the scrotum

and skin of the inside of the thighs. Cancers in this particular region are rare in the remainder of the population. Likewise, workers in tar, paraffin, oils, etc., developed cancers of the hands, arms and other exposed parts with considerable regularity. This led to the experimental use of soots, tars and oils in the production of artificial neoplasms in animals. When the application of the tar is stopped most of the growths disappear, showing they are not real neoplasms, *i.e.*, they are not autonomous. But the cells of a certain few animals do finally develop the capacity to grow without further prodding by the tar. This, and other considerations, lead to the conclusion from which there seems no escape, that in addition to the local there is a constitutional background for the reaction. Can it be postulated that there are some differences in the chromosomes in individuals of the same species, so that chromosomes of some are more apt to take on "cancerous" properties? Any differences must be in the nuclei, because the nucleus controls cell division, and neoplasia is a problem of cell division.

Among other chemicals which produce overgrowths and occasional tumors are Scharlach R, Sudan III, amidoazotoluol and naphthalamin.

Next comes the artificial production of neoplasms by parasitic organisms. Rigid proof has been offered of a parasitic cause only by the work of Fibiger with the rat and of Erwin Smith in plants. The former found a nematode worm in a cancer of the stomach of a rat, obtained a source of supply of this worm in infested cockroaches, fed the cockroaches to rats and about 20 per cent. of them developed cancer of the stomach. Needless to say, rats do not develop spontaneous cancer of the stomach in anything like so high a percentage.

Smith was able to correlate plant tumors with an organism, *Bacillus tumefaciens*, in the sense of the production of an inflammatory reaction going on to malignancy in susceptible individuals, as occurs with tar in animals.

Two more methods remain to be noted: the genetic and the transplantation.

In a certain number of individuals of many species of animals and plants, tumors both benign and malignant appear spontaneously just as they do in man.

There is but one sure way of encouraging the appearance of spontaneous tumors, and that is selective breeding. The mouse has been the victim of most of these experiments. Inbreeding of tumor stock results in an increase in the percentage of animals developing cancer. Thus through genetics a means is had for the artificial production of neoplasms.

Among the details of spontaneous hereditary cancer in mice are these. They rarely undergo regression, but progress continuously or intermittently, produce secondary growths and kill the animal in two to three months. Most of them are glandular cancers and arise in the breasts or salivary glands. The rate of growth in different animals varies considerably.

These spontaneous tumors are the sole source of the transplantable tumors. A transplantable tumor is one, portions of which, when inoculated into other animals of the same species, continue to grow and kill the secondary host. Certain well-studied examples have now become "standard," so to speak, and are kept in stock in many laboratories. Dr. F. C. Wood, of the Crocker Cancer Research Institute, has kept many for a number of years and is gracious enough to supply material to various workers in this field. These include a number of tumors from the mouse, rat and fowl.

Transplanted tumors serve a number of useful purposes but are in deserved disrepute for certain types of work, par-

ticularly curative efforts, mainly because workers forget to use adequate controls. It must be remembered that a transplant does not originate from the cells of the host but from another animal. The combination of tumor and mouse can really, therefore, be looked upon as a sort of tissue culture: the tumor, the tissue; the mouse, the culture medium. Further details of transplanted tumors are that they are notoriously unstandard in their growth and many recede and disappear spontaneously. Thus anything applied which "cures" must be viewed with suspicion, unless rigidly and adequately controlled. When a new transplantable tumor is artificially developed, *i.e.,* transplants taken from a spontaneous one, it takes some time, possibly a year or more and twenty or thirty transplants, until it establishes a sort of "normal" growth for itself. Finally, a given, more or less, percentage of transplants will take, and a more or less uniform number will recede and disappear, in the same strain of mice. If another strain of mice is used, the figures will vary immediately.

This ends, then, the recital of the several major artificial methods of tumor production. But the paper can not be concluded without emphasizing that notwithstanding the diversity of incitants, the result is always fundamentally the same, namely, cell proliferation. Such being the case, the solution of the problem of malignancy belongs to the biologist, and it is on his doorstep that this disagreeable progeny of human living is now squalling.

HELMETS FROM SKINS OF THE PORCUPINE-FISH

By Dr. E. W. GUDGER
AMERICAN MUSEUM OF NATURAL HISTORY

SOME years ago I wrote an article on some unusual uses made of the skins of the puffer fishes, and in this set forth briefly the use of these skins as helmets by certain Pacific islanders.[1] Now advantage is taken of the opportunity to bring together what is believed to be all the known accounts and figures of such helmets used in defensive warfare in the South Seas. These data, which I have been years collecting, are as curious as they are interesting. Various kinds of helmets have been noted in use by various dwellers in Oceania, but the porcupine-skin helmet is not merely restricted to the South Seas proper but, save for two isolated references to nearby islands, all the accounts allege its use in one single group of islands only.

All the dwellers of the Pacific islands have evolved offensive weapons of many varied kinds, but, while scattered references have been found to the occasional fabrication and use of defensive body armor in various islands, it is significant that those who have best developed and most constantly used this armor are the wearers of the *Diodon*-skin helmets. And now, without further delay, let us turn to them.

DIODON-SKIN HELMETS IN THE GILBERT OR KINGSMILL GROUP

The most obstreperous and war-like people of the South Seas are, or at any rate were, the Gilbert Islanders. They of all the dwellers in Oceania have developed the most bizarre offensive arms and the most perfected defensive body armor to ward off attacks with these arms. The American Museum possesses a number of suits of such Gilbert Island armor and a large collection of offensive weapons armed with shark's teeth, but unfortunately it does not have any *Diodon*-skin helmets. However, the finest and best complete suit of such armor known to me is found displayed on a model in the Peabody Museum, Salem, Massachusetts, as may be seen in Fig. 1 herein. For this photograph I am indebted to the courtesy of Mr. L. W. Jenkins, assistant curator of the Peabody Museum. This figure was first published in the "Visitors' Guide to Salem," Essex Institute, Salem, 1916.

Mr. Jenkins has endeavored to trace the source of the materials of this group. The figure itself was modeled sometime in the nineties of the last century and was dressed from objects in the collections of the museum at that time. The exact dates of the armor and accessories can not be given, but Mr. Jenkins thinks that they were collected prior to 1867 when the Peabody Museum received them in taking over the collections of the old East India Marine Society. Probably they date earlier than 1850.

Here then is to be seen a complete suit of coconut fiber (coir or sennit) armor for body, arms and legs. In addition there is a cuirass of more closely woven sennit apparently supported on rods, with a high-standing shield extending above and protecting the back of the head, a *Diodon*-skin helmet covering the head and gauntlet-like structures pro-

[1] E. W. Gudger, "The Puffer Fishes and Some Interesting Uses of their Skins," *Bulletin New York Zoological Society*, 1919, 22: 126–131. 9 text figures.

—*Photograph by courtesy of Mr. L. W. Jenkins*

FIG. 1. MODEL IN PEABODY MUSEUM SALEM, MASSACHUSETTS, OF A GILBERT ISLAND WARRIOR CLAD IN FULL ARMOR, INCLUDING A DIODON-SKIN HELMET.

tecting the hands. These latter are covered with shark's teeth and were probably intended for striking an enemy in the face as much as for warding off blows from the wearer's hands. Grouped around this figure are the offensive arms of his warfare—spears, single- or multi-pointed swords and daggers, all set with shark's teeth and all capable of delivering painful and maybe mortal blows to a man not provided with defensive armor. I can not be sure of the sharks which furnished the teeth save in the case of the dagger or short sword in the figure's right hand. This is set with the sickle-shaped teeth of the tiger-shark, *Galeocerdo* sp.

Such defensive armor would be a very complete and satisfactory protection against attacks with such arms as are shown in the picture, and the double layer over the chest might easily have protected the wearer against musket balls of low velocity propelled by the poor black powder from the smooth-bore muzzle-loading guns of the early days when such armor was actually used in warfare. But on these points let us turn to the first description of both helmet and armor known to the present writer.

This earliest account of the *Diodon*-skin helmet is in volume V of Wilkes's "Narrative" of the United States exploratory expedition into the Pacific in 1838–42. On April 3, 1841, the ships *Peacock* and *Flying-fish* came to anchor off Drummond's Island in the Kingsmill group and there found natives wearing coir armor and fish-skin helmets. It is not my purpose here to enter into any particular description of the armor and a discussion of its uses—that is reserved for another article. However, Wilkes gives a clear-cut account (and one additionally interesting because it appears to be the first) of all these warlike implements, and it seems well to quote him in full, and from later accounts to take only data about the helmets.

—*After Wilkes, 1845*

FIG. 2. TWO WARRIORS OF DRUMMOND ISLAND

KINGSMILL GROUP, CLAD IN NATIVE ARMOR. THE MAN ON THE LEFT WEARS A HELMET MADE OF DIODON SKIN.

These Drummond Island natives came aboard in considerable numbers, and of them Wilkes[2] writes as follows:

The arms and legs of a large proportion of the natives exhibited numerous scars, many of which were still unhealed. These had been made with shark's-teeth swords, such as were seen at the Depeyster Group, weapons which are calculated rather to make severe gashes than dangerous wounds. The spears are equally formidable, and four rows of shark's teeth are inserted in them; some are of the uncommon length of twenty feet, but they are usually about eight or ten feet long, and have prongs projecting from their sides also armed with teeth. A drawing of these arms is given in the woodcut at the end of the chapter.

They were evidently in the habit of having severe conflicts with one another, and war seems to be one of the principal employments of this people.

In order to guard against the destructive effect of these arms, they had invented a kind of armour, which was almost an effectual defence against their weapons, and accounted at once for their arms and legs being the only parts where scars were seen. This consisted of a sort of cuirass, covering the body as far down as the hips, and rising above the back of the head three or four inches. This, when taken off and set upon the deck, somewhat resembled a high-backed chair. It was made of plaited coconut-husk fibres, woven into as solid and compact a mass as if it had been made of board half an inch thick, and was as stiff as a coat of mail. For the legs and arms, they have also a covering of netted sennit of the same material, which they put on. That for the legs resembles a pair of overhauls, such as sailmakers use, with straps over the shoulders. The covering for the arms is drawn on in like manner. The appearance of the body was as if it were clothed in pantaloons and jacket of a deep brown colour. This they must find a very inconvenient covering for their hot climate. However singular the body-

2 Charles Wilkes, "Narrative of the United States Exploring Expedition during the Years 1838, 1839, 1840, 1841, 1842," Philadelphia, 1845. Vol. V, p. 45–46, figures, on pp. 48 and 75.

dress is, that of the head is still more so: it consists of the skin of the porcupine-fish, cut open at the head, and stretched sufficiently large to admit the head of a man. It is perfectly round, with the tail sticking upwards, and the two fins acting as a covering and guard for the ears. Its colour is perfectly white, and by its toughness and spines affords protection against the native weapons.

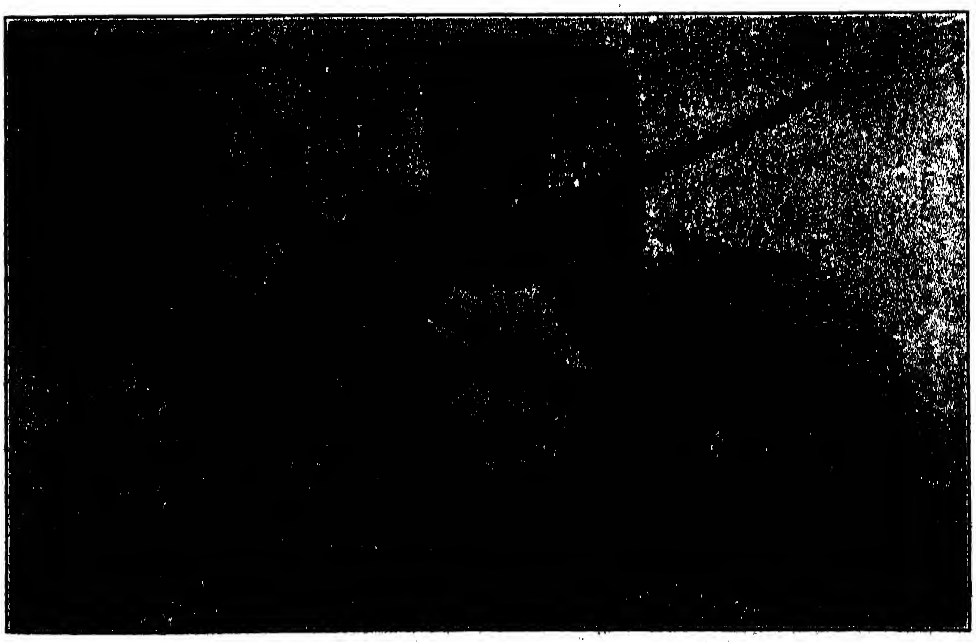
Immediately following the last paragraph above, is a figure (reproduced as Fig. 2 herein) showing two Drummond Islanders wearing this armor. One man has a *Diodon*-skin helmet, but this does not have the pectoral fins acting as ear-protectors as stated in the text. The other warrior has a helmet *manufactured* (probably out of sennit) in contrast to that of his companion which was *grown* —on a fish. Finally Fig. 3 herein reproduces Wilkes's tailpiece at the end of his chapter dealing with the Kingsmill Group. Here are shown the helmet, the cuirass and two lances armed with shark's teeth—one of these being three-pointed.

Dr. John Coulter[3] visited Utiroa village, Drummond Island, about 1845, and found the defensive armor as described by Wilkes. Of the helmet he writes that "The head is surmounted by an extraordinary looking apology for a helmet, in a conical shape, and made of dried fishes' skin, with two or three feathers stuck in the top for a plume." Later he speaks of it as "resembling a painter's paper cap." A native chief presented him with one of these helmets.

George French Angas, in his book, "Polynesia," etc.,[4] speaks of his visit to the Kingsmills where he records of the natives that "on the head is worn a cap

[3] John Coulter, "Adventures on the West Coast of South America and the Interior of California, Including a Narrative of Incidents at the Kingsmill Islands," etc., Vol. I, pp. 191, 207 and 214. London, 1847.

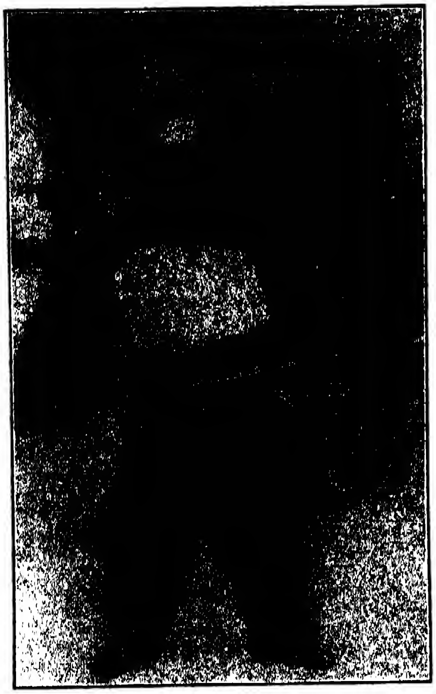
[4] London, 1866, pp. 394–395.



—*After Wilkes, 1845*

FIG. 3. ARMS AND ARMOR

INCLUDING A HELMET OF DIODON SKIN—OF THE DRUMMOND ISLANDERS.



—*After Hartzer, 1900*

FIG. 4. A GILBERT ISLANDER WEARING A DIODON-SKIN HELMET, COCONUT COIR ARMOR, AND A "STOMACHER" OF SHARK OR RAY SKIN.

formed of the skin of the porcupine-fish, bristling with sharp spines and ornamented with a few feathers at the top." The other armor both offensive and defensive was as described by Wilkes.

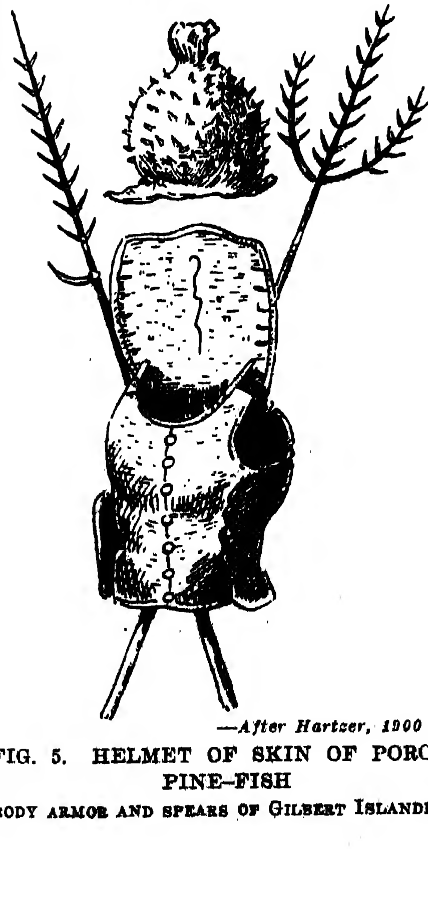
Wm. Wyatt Gill, the South Seas missionary, in his various books has given us many interesting first-hand natural history notes. In his "Jottings from the Pacific"[5] he relates that in 1872 he spent a day at Nukunau, one of the Gilbert Islands. Here the natives came aboard with curios to sell the white strangers. Among these were helmets of the porcupine-fish's skin.

In 1890, James Edge-Partington published volume I of his great "Album of the Weapons, Tools, Ornaments, Articles of Dress, etc., of the Natives of the Pacific Islands." On plate 170 of this volume he shows a native of the Kingsmill Group clad in the regulation armor of these islands. The helmet, however, has ear lappets of *Diodon*-skin depending from the helmet proper—something not heretofore found. His figure is not very distinct, and, as better ones are to follow, it does not seem necessary to reproduce it here.

Fernand Hartzer,[6] a Catholic missionary, wrote in 1900 that the Gilbert Islanders wear "a casque fashioned out of the dried skin of a large fish with strong spiny scales." His photographic figure shows a native clad in coconut sennit armor covering the whole body, but having instead of the cuirass a girdle

[5] London, 1885, p. 147.

[6] Fernand Hartzer, "Les Iles Blanches [Archipels Gilbert et Ellice] des Mers du Sud," p. 85, figure to face p. 284. Paris, 1900.



—*After Hartzer, 1900*

FIG. 5. HELMET OF SKIN OF PORCUPINE-FISH BODY ARMOR AND SPEARS OF GILBERT ISLANDERS.

—*After Krämer, 1906*

FIG. 6. MEN OF TAPITUEA, GILBERT ISLANDS
WEARING DIODON-SKIN HELMETS, CLAD IN ARMOR AND HOLDING SPEARS.

of shark or ray skin. On his head he has the *Diodon*-skin helmet with ear lappets which protect the temporal regions as well as the ears and apparently extend across the back of the head. Hartzer's figure is so much more distinct than Edge-Partington's that it instead of his is reproduced as Fig. 4 herein. This suit of armor is a bad "fit" for the wearer, being evidently made for a much taller man.

The source of Hartzer's figure is a matter of some interest. It is somewhat doubtful if it originated with him. On page 85 of his book is a pen-and-ink drawing labeled "Armes, Casques et Cuirasses des Naturelles des Iles Gilbert" which shows such marked resemblances to Wilkes's figure that one is led to wonder if it is a not distant copy of his illustration. It is reproduced herein as Fig. 5.

Augustin Krämer journeyed widely through the central Pacific and studied those peoples with a discerning eye. In 1906 he published an extensive account of

—*After Hambruch, 1915*

FIG. 7. WARRIOR OF BONABE ATOLL GILBERT GROUP, WEARING HELMET AND BODY ARMOR. NOTE THE PAD OF SOFT MATERIAL PROTECTING THE WEARER'S HEAD FROM THE HARSH SKIN OF THE FISH.

his travels.[7] At Tapituea in the Gilberts the natives came in numbers to see him, bringing all sorts of ethnological objects, particularly offensive and defensive armor. The men willingly armed themselves and posed for him to make photographs. Two of these he reproduces in his book, and of these his "Bild 37" is reproduced in part herein as Fig. 6. The man on the left has on trunk armor and helmet, the second is likewise clad plus the "overhauls" of Wilkes's account. Warriors numbers three and four have on only the "stomacher" and the helmet respectively. At least one of the helmets has the ear lappets previously referred to.

These data for this island Krämer repeats in his ethnological work "Südseearbeiten," etc.[8] Here he distinctly says that the "stomacher" or girdle is made of the thorn-studded skin of a ray common in the Gilberts.

Hambruch[9] in 1915 figures a warrior from Bonabe atoll, Gilbert Group, wearing all the armor save the stomacher. His figure is reproduced as Fig. 7 herein partly because it is an excellent figure, but more because it shows what none

[7] Augustin Krämer, "Hawaii, Ostmikronesien, und Samoa. Meine zweite Südseereise (1897–1899) zum Studium der Atolle und ihren Bewohner," p. 272, Tafel 11, Bild 37. Stuttgart, 1906.

[8] Abhandlungen Hamburgischen Kolonialinstituts, 1914, Bd. 14, pp. 229–230.

[9] Paul Hambruch, Nauru, 2. Halbband. (In Ergebnisse der Südsee Expedition 1908–1910 [Hamburgische Wissenschaftliche Stiftung], II. Ethnographie B. Mikronesien, Bd. I, 1915, pp. 169–175. Tafel 27, fig. 2.)

—*After Alexander, 1908*

FIG. 8. A MARSHALL ISLAND WARRIOR WITH BODY ARMOR AND WITH HELMET OF DIODON SKIN.

—*After Mayor, 1916*

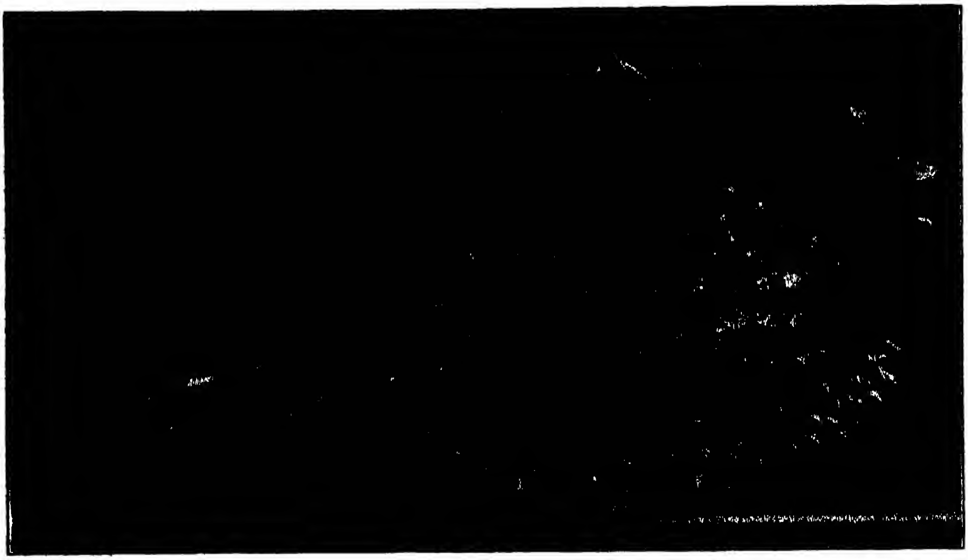
FIG. 9. A WARRIOR OF TARI TARI [BUTARITARI?]
GILBERT ISLANDS, DRESSED IN COCONUT-FIBER ARMOR AND SHARK'S-SKIN BELT, AND HOLDING WEAPONS EDGED WITH SHARK'S TEETH.

other known to me does—*i.e.*, the pad or lining which protects the wearer's head from the harsh skin of the fish.

My friend, the late Dr. Alfred G. Mayor, many years ago traveled extensively throughout the South Seas with Dr. Alexander Agassiz. He was an expert photographer and fortunately made many such records of the country, the people and their possessions. In 1916[10] he published the figure and legend reproduced herein as my Fig. 9. The man portrayed wears a complete suit of woven coir armor, and his chest is still further protected by the closely woven coir cuirass. In addition the abdominal region is very efficiently protected by a stomacher of thorny dried ray skin which overlaps the lower edge of the cuirass. On his head is a *Diodon*-skin helmet with large lappets plainly intended to cover the ears. The figure shows better than any yet given the details of the armor.

The text contains no reference to the figure and unfortunately no date is assigned to this picture, but it was probably taken about 1900. It is but one of several poses sent me by Dr. Mayor. It is the most complete suit of armor yet

[10] Alfred G. Mayor, "Men of the Mid-Pacific," SCIENTIFIC MONTHLY, 2: 10, figure, 1916.



—*In the collections of the American Museum*

FIG. 10. A DRIED INFLATED PORCUPINE-FISH, SEEN IN SIDE VIEW

shown on a living man—the wonderful suit shown in Fig. 1 being from a model.

Diodon-skin Helmets in Nauru

In his book on Nauru previously referred to, Hambruch (1915) expressly says that "the spiny skin of the *Diodon* fish is used for helmets." For an illustration, however, he gives the figure of that from Bonabe, Gilbert Group, reproduced herein as Fig. 7, since it is a better one. Now Nauru, Nawodo or Pleasant Island is an upraised coral atoll, a solitary outlier about three hundred miles to the west of the Gilberts. It is commonly reckoned as a member of this group, to which it belongs politically, but it seems to me that to assign it thus physically is straining matters considerably. The people are, I believe, much the same culturally, and it is probable that they got their idea of armor (which is certainly almost identical with that from the Gilberts), including the *Diodon* helmet, from these islands. However, it seems best to record the helmet from Nauru separately as is done herein.

Diodon-skin Helmets in the Marshall Islands

One solitary figure (without explanatory text) has been found of such a helmet in islands other than the Gilberts or their dependency, Nauru. But of the accuracy of its labeling, like the Scotsman, "I hae me doots." Fig. 8 herein (labeled simply "Marshall Island Warrior") is taken from a book by another South Seas missionary.[11] Here is portrayed a native wearing coconut sennit armor reaching only to the waist, over this a cuirass and on his head the usual helmet of the skin of the porcupine-fish. This has lappets over the ears and a back piece covering the nape of the neck.

That this and other photographs reproduced in Alexander's book are originals is more than doubtful. Some are straight commercial photographs, while most are copied from other books, as we learn from a general statement in his preface. However, save in two cases only, on none of the figures is there any

[11] James M. Alexander, "The Islands of the Pacific," figure to face p. 320. New York, 1908 (first ed. 1895).

direct reference to or acknowledgment of the source. Many are plainly taken from Cook's and other "Voyages." For instance, on the insert plate to face p. 314 is Wilkes's figure (reproduced herein as my Fig. 2) of the two Drummond Island warriors, without indication of source and bearing the legend "Heathen Micronesians." This, of course, leads one to doubt the accuracy of assigning this armor to the Marshall Group. This doubt is strengthened by the fact that in an extensive reading of books of travels in the South Seas no reference other than this has ever been found to armor in the Marshall Group. This is particularly significant when a careful search through Krämer (see citations above) reveals no reference to any sort of armor in the Marshalls, although he gives two figures showing this armor in the Gilberts. Incidentally it may be said that few travelers have had more detailed knowledge of the people of the Marshall and Gilbert Islands and of their customs than Krämer.

This same negative evidence is strengthened when one turns to the most extensive ethnological study ever made of the Marshall Islanders. In 1914, P. A. Erdland published his "Die Marshall Insulaner—Leben und Sitten, Sinn und Religion eines Südsee-Volkes."[12] In this there is a chapter, "Waffen und Krieg," which contains neither figure nor reference to arms and armor such as Alexander portrays.

In conclusion it may be said that while the Marshall Islands are like Nauru near the Gilberts (as distances go in the South Seas) and while their inhabitants are of the same general stock

[12] Anthropos, Bd. 2, Hft. 1, 376 p., 14 pls., 27 text figs. Münster, 1914.

FIG. 11. THE SAME FISH SEEN "HEAD ON"

and have much the same manners and customs, still there is no positive evidence (as there is for Nauru) that they made use of the *Diodon* helmet. They may have done so, but it is strange that no authentic records have been found.

How These Helmets Are Made

The puffer, globe or porcupine-fishes have the ability to inflate themselves by taking in water or air until the stomach and indeed the whole body is distended balloon fashion, as may be seen in Figures 10 and 11. If killed while distended and allowed to dry in this condition, then by cutting off the head end of the fish, removing the internal organs and providing some kind of lining (such as may be seen in Fig. 7), such helmets will be made as are shown in the various figures. The scales in these fishes have been changed into long thornlike spines. When the fish is in its ordinary condition (relaxed), these lie flat on the skin. But when it is fully inflated with air or water these stand out literally like "quills upon the fretful porcupine" and hence give the fish one of its trivial names. In this condition I have see the fish float along, carried by winds and currents.

That such a helmet of stiff dried skin with its supporting and strengthening horny spines is capable of warding off or at any rate deadening blows, such as those inflicted by the weapons shown in the figures, can not be doubted. However, in addition the aspect of a warrior wearing such a helmet was probably relied on to strike terror in the heart of his opponent. In short, it must be admitted that the dried *Diodon* skin makes a fairly effective helmet for the Gilbert Islander.

COLLECTING LEAF-MINERS ON BARRO COLORADO ISLAND, PANAMA

By Dr. S. W. FROST

THE PENNSYLVANIA STATE COLLEGE

It hardly seems necessary to describe the geography of Barro Colorado Island, visited by so many naturalists and scientists during the past few years and located as it is in the path traveled by numerous tourists who visit Panama yearly. However, few except the scientists that traverse the canal know much about the island. Standley, Kenoyer and others have written about its plants, Chapman concerning its birds and animals and Allee of its ecology, and further bits of natural history have been contributed. But the average traveler passes the island with no knowledge of the wealth of plant and animal life preserved by the Institute for Research in Tropical America and no knowledge of the numerous scientists that visit the place every year to learn more about tropical life. To the ordinary tourist, Barro Colorado Island appears as a group of tropical trees, enchanting foliage or jungle melting into the shoreline as his steamer passes.

The island is located in a country rich in history and stories of Spanish conquest and plunder and has been on

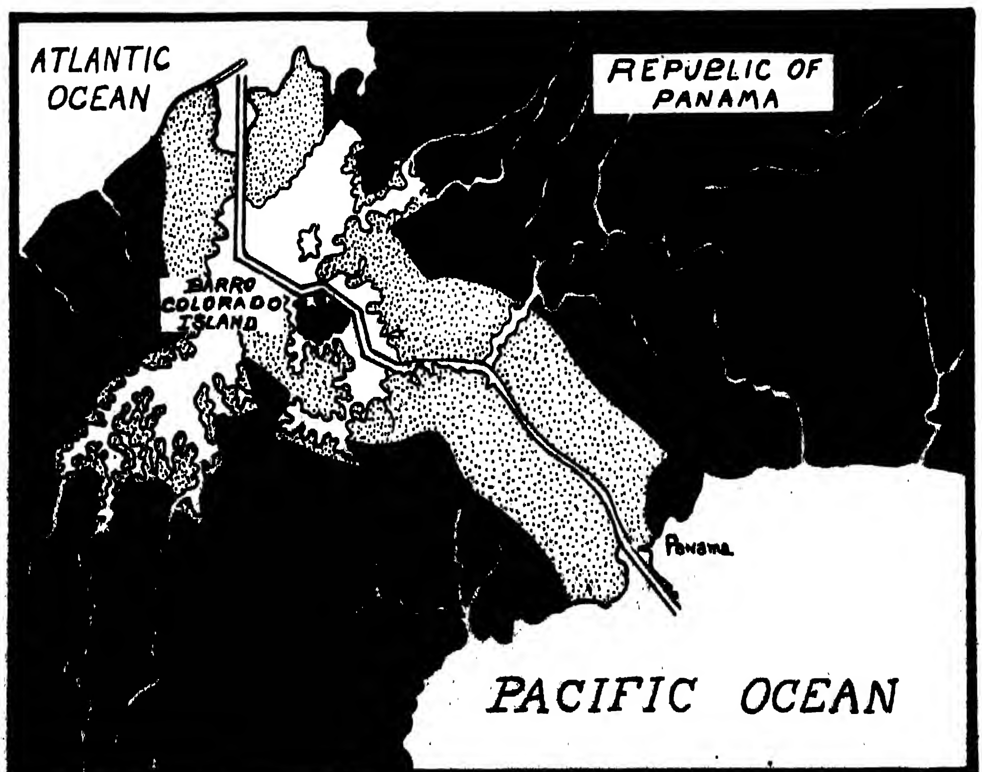


FIG. 1. SKETCH OF THE CANAL ZONE, PANAMA
SHOWING GATUN LAKE AND BARRO COLORADO ISLAND.

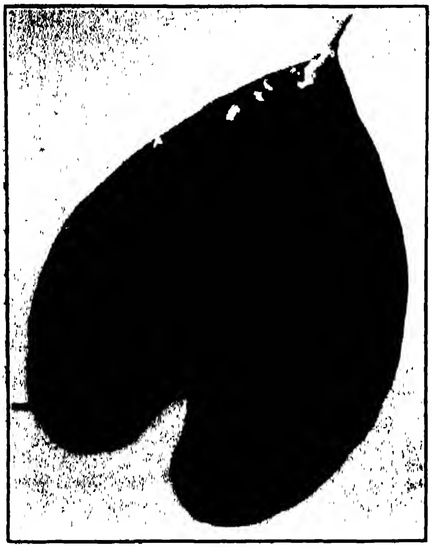


FIG. 2. THE PIPERS

ARE AN OUTSTANDING GROUP OF PLANTS. MANY OF THE SPECIES SHOW THE LONG TORTUOUS MINES OF ONE OF THE LEPIDOPTERA. *Piper smilacifolium* FIGURED.

the highway between the Atlantic and the Pacific for centuries. To-day great steamships glide by its shores *en route* to all points of the world. Panama and Barro Colorado Island have thus become easily accessible to all who wish to study life in the tropics.

The writer's sojourn of four months on Barro Colorado Island was directed to an intensive study of the leaf-mining insects. They are not large, conspicuous and at first sight attractive, like trees, animals or birds, but when one becomes acquainted with them and learns about their interesting and highly specialized habits, they make up in interest what they lack in size. Most of the naturalists that have traveled the trails of the island or in fact any part of the world where grasses, shrubs or trees grow have noticed the winding galleries or blotches produced by these insects upon the leaves. The fact that they have been observed by so many but understood by so few warrants some remarks.

Leaf-miners are among the smallest of the plant-eating animals, and they seldom measure more than a quarter of an inch in length, with a great majority of them even smaller. In general, the tropical species are similar in habits to those of the temperate regions, but they are more numerous and almost entirely different from those we have in the north. The abundance of the foliage of the tropical forests is in itself inviting to them.

The larvae of these insects work between the upper and lower epidermis of the leaf, feeding upon the cells or juices of the plant. The cavity they excavate serves as a resting place as well as supplying them with food. Some produce long tortuous mines (Figs. 2 and 3);

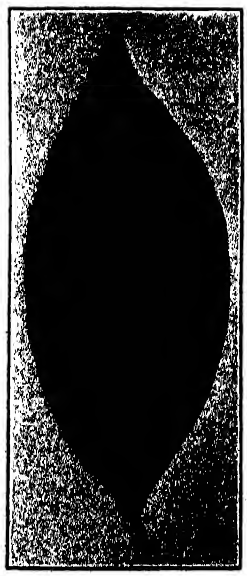


FIG. 3. SOME MINERS ARE SO UNIVERSALLY PRESENT

ON CERTAIN SPECIES OF PLANTS THAT THEY SEEM ALMOST A CHARACTERISTIC PART OF THE PLANT. THE WAXY LEAVES OF *Macrocnemum glabrescens* INVARIABLY SHOW THE MINES OF A SPECIES OF LEPIDOPTERA.

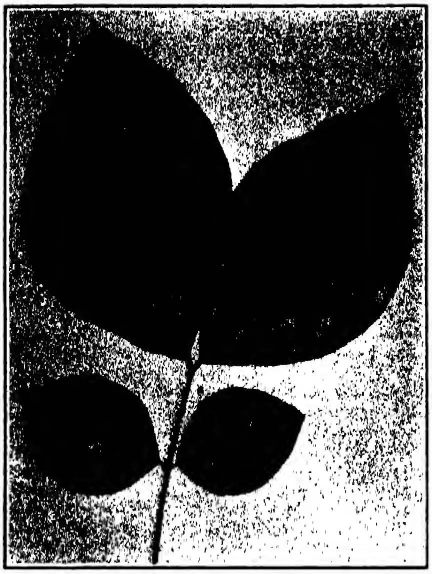


FIG. 4. A LOW-GROWING SENNA
Cassia bacillaris, IS COMMON IN GRASSY PLACES. ONE OF ITS MINERS, A HISPID BEETLE, MAKES LARGE BLOTCH MINES IN THE LEAVES AND DOES CONSIDERABLE FEEDING ON THE LEAVES.

others produce blotch mines (Fig. 4), while still others form mines intergrading between the blotch and the linear type (Fig. 5). Many of the species make their pupae or cocoons in the mines while others cut their way from the mine and pupate outside of the leaf or cut cases from the leaf which are sewed together with silk (Figs. 6 and 7). Numerous beetles, especially the Hispids, do considerable feeding on the leaves before ovipositing (Fig. 4). These are but a few of the many habits among leaf-miners, and almost every observation reveals some new or interesting habit.

The writer had opportunity of studying the habits of many of these miners. Some are most intricate and serve even to distinguish different species. The habit of cutting out cases for pupation is common to some moths, beetles and sawflies and will illustrate this.

A certain Lepidoptera, still undetermined, makes broad linear mines on *Psychotria marginata*. When ready to pupate it cuts a circular or oval case from the leaf, which is illustrated in Fig. 6. At the edge of the mine, the larva eats out a clear portion, circular in outline, removing all the tissue between the two epidermal layers. The larva then begins to cut through both surfaces of the leaf at the edge of the circle, drawing them together and fastening them with silk as it continues cutting. When finished the case is completely cut and sewed together except at one point where it is attached to the original mine. This apparently prevents it from falling prematurely. The connecting portion is sewed with silk but not cut by the larva. As the two small pieces of leaf, which now form the case, begin to dry and shrink, the case is automatically severed or twisted from the leaf and it drops to the ground, leaving a small oval or rounded hole in the leaf.

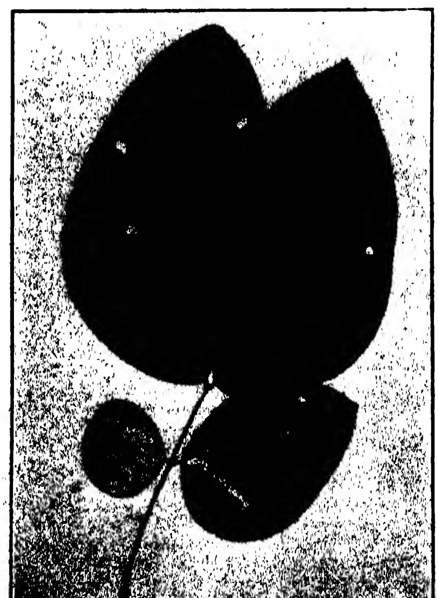


FIG. 5. A FLY, AGROMYZIDAE
ALSO ATTACKS *Cassia bacillaris*, MAKING LINEAR OR LINEAR-BLOTCH MINES.

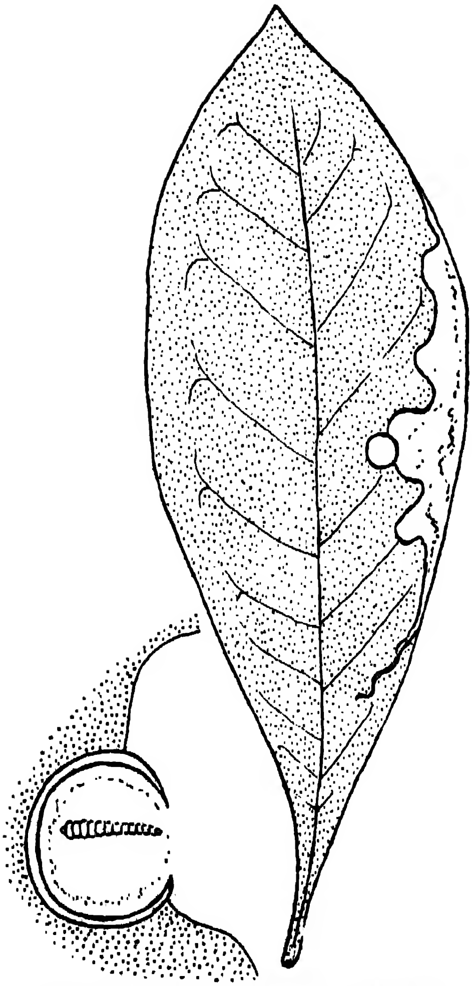


FIG. 6. MINERS ARE PARTICULAR IN THEIR HABITS

Psychotria marginata OFTEN SHOWED THE MINES OF A LEPIDOPTERA. THE ENLARGEMENT SHOWS HOW THE PUPA CASE IS CUT FROM THE LEAF.

Another species, a beetle, *Pachyschelus atroviridis* Fisher, mining on Serjania, cuts its case in a very different manner (Fig. 7). The larva makes a rather broad linear or blotch mine and when ready to pupate cuts a circular case at the end of its mine. As before, a clear round area is mined, the larva removing all the cells between the upper and lower epidermis. Then the larva commences cutting around the edge of this area, severing both the upper and lower epidermis, completing the circle but leaving a vein here and there to hold the case in position. The diameter of the case is about the length of the larva, and by revolving it seems able to maintain the geometric form of its case with considerable accuracy. As the case is cut from the leaf the edges are drawn together and sewed with silk. When complete the case is suspended by two or three veins in position in the leaf. The larva is very active and by sudden twists of its body it is able to break the case from the leaf. This is done with considerable force, and sometimes the case flies a long distance from the leaf and even makes a slight clicking sound as it strikes against the side of the rearing chamber.

Leaf-miners are abundant, and they have been unconsciously and unintentionally taken by botanists or those collecting plants for other purposes. Some of the mines are so plentiful that it

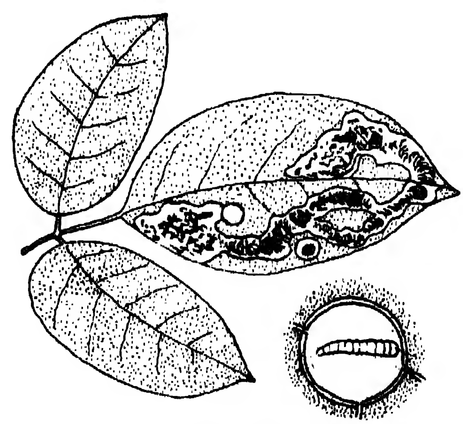


FIG. 7. A LEGUMINOUS PLANT, SERJANIA

GROWS COMMONLY ON THE ISLAND, AND IT IS EQUALLY AS COMMON TO FIND THE MINES OF A BEETLE *Pachyschelus atroviridis* UPON ITS LEAVES. THE ENLARGEMENT SHOWS ITS METHOD OF CUTTING A CASE.

FIG. 8. CLIMBING FIGS FORMED NATURAL LADDERS
FOR THE ENTOMOLOGIST TO REACH THE TOPS OF TALL TREES.

would be difficult to secure a specimen of the plant without also taking specimens of the mines. The work of these miners has even crept into the publications of botanists. In the temperate climate, where columbine grows, one invariably finds the mines of an Agromyzid. The linear mines of this species are almost as characteristic as the plant. Likewise, on Barro Colorado Island, the waxy leaves of *Macrocnemum glabrescens* (Fig. 3) or the biparted leaves of *Cassia bacillaris* (Figs. 4 and 5) are sure to reveal the characteristic operations of their miners. Sometimes 100 per cent. of the leaves of the former striking shrub or tree may be infested with the larvae of a small moth. They prefer to mine the young unfolding leaves, and tenanted mines can seldom be found on the older leaves. Later each larva forms a cocoon at the end of the mine, folding the leaf slightly at this point. Cassia was frequently attacked by a Hispid beetle. The adults fed abundantly upon the leaves and the larvae mined the leaves. If in their operations these beetles left sufficient area unmined, a species of fly (Agromyzidae) would make its linear mines. These two seemed to compete for a living on the same plant.

Leaf-miners are unquestionably more abundant in the tropics. On Barro Colorado Island, the moths (Lepidoptera) were found most abundant, and the species of Lithocolletis, Lyonetidae and Marmara were especially numerous. Marmara was found on various aroids and upon the fruits of the passion flower. The beetles (Coleoptera) came next in importance, and of these the Hispids were most conspicuous. These beetles were often collected along the shady trails especially where a little of the late afternoon's sun trickled through the jungle. Several species of Buprestidae were reared as leaf-miners. *Pachy-*

FIG. 9. AROIDS SOMETIMES GREW CONVENIENTLY UPON STONES OR MIGHT BE OBTAINED FROM FALLEN TREES.

schelus atroviridis, a small bluish-colored beetle, was somewhat common and was frequently seen ovipositing upon the leaves of its favorite food plant, Serjania. A few flies (Agromyzidae) were reared from plants that were abundant in the more open, sunny and grassy places on the island.

There were many conditions that made the study of leaf-miners most interesting. It was the writer's first trip to the tropics, and not only were the insects new to him, but the birds, plants and animals were all strange, and at first he found himself somewhat lost in his new surroundings. In the course of a few days, however, certain plants and miners became familiar although their names were often still unknown. This trip was of special interest because no previous worker has gone to the tropics to make a particular study of leaf-miners. It is true that many entomologists have collected insects in Panama and some even upon Barro Colorado Island, but their interests were not devoted primarily to leaf-mining insects. In their efforts they collected a good many of these insects, but too often the adults were acquired with no knowledge of the plant on which they fed or bred. Often small specimens of the plant were brought back which were too meager to be correctly determined. The writer therefore made an effort not only to collect the adults but also to secure all possible information concerning their habits and to obtain a fair portion of the plant on which they were mining or feeding. The mines were gathered with the larvae or grubs at work in the leaves. These were placed in suitable rearing or breeding jars and left until the adults emerged, when they were immediately pinned. Eggs, larvae and pupae, when possible, were preserved, drawings were made of the different types of mines and leaves were pressed representing the plant as well as the mines. Such collections meant not only the duties of an entomologist but those of a botanist as well, and the writer was confronted with all the difficult problems of both specialists.

The leaf-mining studies were therefore at times difficult. About 50 per cent. of the plants of the tropics are trees and shrubs. The grasses, spurges and other low-growing plants of the temperate zone become shrubs and trees in the tropics, increasing to a considerable extent the difficulty by raising the foliage beyond reach. To obtain specimens of adult insects at these higher levels was even more difficult than collecting the leaves. It was tantalizing to see a desired insect flying just beyond reach. Recent fallen trees or twining figs, forming natural ladders, often helped to reach the tops of such trees. The climbing irons and the old method of shinnying also helped at times. But sometimes after all this effort and after placing the insects in rearing cages and waiting several days for the adults to emerge, one found that they had been parasitized and his labors were in vain. On rare occasions ants gained entrance to the rearing jars and removed the heads of the prized insects or mutilated them in other ways, rendering them useless to the taxonomist. Certain species of fungus frequently twined its mycelium about the antennae and legs of the specimens, which was quite annoying to the entomologist.

It has been stated that approximately seven hundred seed plants are known to occur on Barro Colorado Island. It is evident that a large number of these have their miners. Nearly three hundred plants were collected on the island bearing the mines of insects. These were kindly determined by Dr. Paul Standley. Judging from this it would be safe to say that about 70 per cent. of the plants are attacked by leaf-miners. It should be remembered that some miners attack several species of plants, and, on

the other hand, certain plants are mined by several species of insects. Such conditions obtain in the temperature regions and possibly to a larger degree in the tropics. Among the ferns only the Polypodiaceae are known to harbor mines, while the oaks of the temperate zone have over fifty species attacking their leaves.

The size of the leaves and the abundance of the foliage are favorable for leaf-miner development. Fifty specimens of a species of Marmara were taken from a single blade of a large-leaved aroid. Compare this with the clover of the temperate zone where usually a single miner occurs on a leaflet. Kenoyer has stated that a given area in the tropics will support twice the number of species of plants as a similar area in the temperate climate. This means a greater range of plants for the leaf-miners. Unlike many insects leaf-miners seem to be very active even during the dry season.

Barro Colorado Island, at least in its eastern portion, does not present a virgin forest as it was touched by civilization in the early days. Some plants, such as banana and pineapple, have been introduced and planted on the island, but it is doubtful whether any leaf-mining species have been introduced. Care must always be taken in this respect, for leaf-miners are readily introduced on plants bearing leaves. Barro Colorado Island certainly affords an excellent, tropical, rain-drenched forest for studying leaf-mining insects, and the writer was surprised at the great abundance of these species. If it is true that the plants of the island have not been fully exploited then the subject of leaf-miners has been but scratched upon the surface.

THE DELUSION OF PROGRESS

By Dr. JOHN HODGDON BRADLEY, JR.
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I

FACTS concerning the nature of the physical world grow many and fast in the jungle of modern science. There are a few trails, some known to lead only to more bewildering depths, others that seem to reach the edge of the tangle and the light. The scientist can not be sure of what he sees at the end of an outbound trail because he is a dweller of the thickets and his sight is poor. More than once, while peering out, new facts have sprouted around him before he had focused clearly on the far horizons. He can not be sure that what he saw was not a dream of his own fabrication. And yet, despite his misgivings, he has seen strange things at the ends of several trails. So consistent with each other were the things he saw, he believes that perhaps he has really had a glimpse of the larger world outside.

Among other things, the scientist thinks he has seen a turning in the long lane of infinity. He thinks he has seen certain boundaries to the universe of space and time. And he detects a definite order of movement in the vast procession of forms and events which gathered behind the fog-banks of the past and has been slowly marching toward the mist-veiled future. The concept of evolution has grown in nearly every branch of natural science, and with it the belief that evolution, whether of an atom, a man, a planet or a star, travels along definite lines. That these lines are not straight but decidedly curved, and in some cases nearly circular, is one of the most inclusive and significant generalizations in the modern conception of the material world.

The cyclical recurrence of certain natural phenomena has long been apparent. Day and night, summer and winter, the phases of the moon are the most obvious and consequently were the earliest cyclical phenomena to be observed. Such relatively simple cycles must have been in the mind of Tacitus when he said, "In all things there is a kind of law of cycles." With the discovery and the perfecting of the telescope, more obscure celestial cycles, such as the revolutions of the planets around the sun, were observed. Finally, with the growth of modern science, the concept of cycles was expanded to include not only the revolutions of objects in space but also their evolutions in time. If modern art liked curves as well as straight lines and angles, it might depict on its canvas the views of modern science concerning the dynamic universe. In the picture would be countless circles, ellipses, spirals and arcs, the larger embracing the smaller, a separate line for each phenomenon. Along its proper curve, the modern equivalent of destiny, each entity travels its plotted course.

The history of astronomy illustrates the growth of the concept of cycles. Copernicus, by proving that the planets move about the sun in subcircular orbits, opened the road for subsequent investigations into the vagaries of celestial bodies. To-day there is a growing belief that such bodies not only travel along curves but also evolve in cycles. Stars, for example, fall into color groups which grade imperceptibly from red, through yellow to bluish white, apparently in the order of increasing temperature. Many astronomers believe that stars originate

from gigantic whirls of highly attenuated gas. Under the strange pull of gravity the gas particles are drawn together, temperature increases with an increase of friction, and the young star glows red. With continued contraction sufficient heat is generated to impart a yellow tinge to the maturing star. Eventually adulthood is reached and the star shines blue-white in the intensity of its heat. A decline follows wherein contraction continues but heat is dissipated. The star reverses the order of its color changes, returns through yellow to red, and completes the cycle of its evolution. According to the theory, every star in the firmament lies in some stage of this cycle. The old red star is far denser and smaller than the young red star, so that the evolution does not proceed in a perfect circle. It does, however, lead the star in old age to a condition which appears to be similar in many ways to the condition of its youth.

II

Certain modern views in the science of chemistry support this concept of stellar evolution. Although the dominating belief of the nineteenth century was that all matter is composed of rigid units, there were philosophical chemists who thought that the apparent stolidity of the chemical elements was merely the result of imperfect observation and experiment. Mendeleef had brilliantly demonstrated the relationship of the elements in his "periodic law," by means of which he was able to prophesy the existence of three unknown elements which were later discovered. This intimacy of relationship argued a common origin for the fundamental building-blocks of the material world.

With the discovery of radioactivity and later of radium, the instability of an element was actually observed. When the evolution of helium from lead was discovered, science finally had demonstrable proof of the transmutation of one element into another. Subsequent study of the heavyweights of the physical world, thorium and uranium, proved that those elements suffer a progressive disintegration resulting in more than thirty different substances that vary widely in their properties and are distinctly different from their parents. It was learned that two new kinds of lead existed, one derived from the decay of thorium, the other from the decay of uranium, each differing from the other and from normal lead in atomic weight and specific gravity. Thus the doctrine of evolution among the very units of matter began to seep into the science of chemistry even as parallel beliefs regarding plants and animals had already entered and possessed the science of biology.

It is too early to know just how far the disintegrative evolution of the heavy, complex radioactive elements is true of the lighter, simpler elements. It is clear, however, that the stability of any substance is relative to the temperature, pressure and chemical conditions under which it exists. The spectroscope shows a distinct correlation between the color and the chemical make-up of stars so that there appears to be a parallelism between the evolution of a star and the evolution of the materials of which it is constituted. The hottest stars seem to be composed of the simplest, lightest and most stable elements, chiefly hydrogen and helium, whereas the cooler stars contain more of the complex, heavier and less stable elements. Despite the multiplicity of factors and the probability that other solar systems have quite different combinations of materials from our own, it seems likely that on any cooling star there must be a consequent evolution of the elements.

A clock that is not wound up runs down. Cooling stars are clocks that are running down, and unless rewound they

are destined to pass into dark dead bodies of which there are probably many in the universe. The fact that they are running down is sufficient proof that they were once wound up. A more graphic proof is the phenomenon of the novae, insignificant stars that suddenly flash into great brilliance and after a short time fade out to their former dimness. Whatever may cause the sudden flaring of these "new stars," they show to the telescope a rapid stellar evolution from cool to hot to cool. To the spectroscope they show a parallel evolution of their chemical elements from complex to simple to complex.

Some scientists believe that the phenomenon of novae presents a rapid epitome of the basic cycle of evolution in the whole stellar universe. Stars evolve from relatively cool diffuse nebulae to white-hot stars, then return to relatively cool compact stars and finally to cold dead stars and planets. This cycle from cool to hot to cold is paralleled by a chemical evolution from complex to simple to very complex. Modern science has not accepted this view without reservations, but it is converging along several roads to a belief in an evolutionary movement of matter through space and time, a movement in a rude cycle which returns materials after wide variation to conditions of their past.

III

Man's chief interests are rooted in the earth, and we do not have to leave the surface of our own planet to see a variety of evolutionary cycles. Many of the processes by which the earth has been molded have curved through time with untiring repetition. Whatever our guess as to the pregeological stages of earth history, we have a tangible record of later events in the rocks. Locked within them are several hundred million years of history. Part of their story has already been recovered, and it is a story of cycles.

The oldest rocks undoubtedly congealed from a liquid not unlike the lavas that pour from the mouths of active volcanoes. We have no record of these oldest rocks because they are buried beneath younger formations, but we do have rocks of the same genre formed at a later date. These are the igneous rocks of many places and ages, the most primitive of all rock types. Nearly all the ninety-odd chemical elements known on earth have been found in this kind of rock. The elements combine in intricate unions to form a large number of rock varieties. Only a few of the elements occur in any great quantity. Oxygen, silicon, aluminum, iron, calcium, magnesium, sodium and potassium constitute nearly all the earth's substance. The last seven are usually combined with oxygen in a chemical partnership called an oxide, a few of which are among the most abundant substances in rocks. Most of the oxides are basic, but the commonest one, silicon dioxide, is acid. The result is that the basic oxides of alumina, iron, lime, magnesia, soda and potash combine with the acid silica to form a variety of silicate compounds. A few of these, as in the case of the oxides, predominate. The common oxides and silicates assume many different mineral forms, but here again only a few predominate. So it is that when an igneous rock freezes from its parent liquid, a selective process works, first on the chemical elements, then on their oxides and silicates and finally on the minerals. The result is that certain chemical combinations in certain mineral forms become of prime importance.

Rocks so constituted are the parents of all other rocks. Exposed at the surface of the earth, they suffer the attack of the physical instruments of destruction, an army in whose ranks march such redoubtable warriors as frost, wind, mov-

ing ice and running water. With these come the insidious gentlemen of the secret service, the chemical instruments of decay, weakening the rocks from within by solution, hydration, carbonation and oxidation so that they may be more easily blasted from without. No rock can forever withstand such an attack. The forces of geologic destruction do not know defeat.

The products resulting from the disruption of the igneous rocks are scattered far and wide. Some find rest on the surface of the land as loose earth and gravel, a mantle for the bony framework of the continents. Some are carried as mud, sand and gravel to lakes and ocean basins. Here they are dropped, usually in layers. During transportation the mineral and rock particles are rearranged according to weight and size so that the resulting deposits are in many cases well sorted, the heavy materials separated from the light and the coarse from the fine. Such rock waste, whether of land or sea, may later be compacted and cemented into a new rock type, the sedimentary rocks so widely exhibited at the surface of the earth.

The chemical processes involved in the making of sedimentary rocks are as significant as the physical. The complex silicates of the mother rocks are rather generally reduced to simpler compounds. The oxides and silicates of aluminum become deposits of clay and silt; much of the calcium and magnesium contributes to the formation of limestone and dolomite; the iron oxides become iron deposits or are scattered widely as coloring pigments in a variety of rocks; the sodium and potassium oxides are for the most part dissolved and held in seawater. The silicon dioxide, in the form of the mineral quartz, is the most resistant constituent of the parent igneous rocks. It survives chemically unchanged in sand and gravel deposits.

Nature is not content with forming simple sedimentary rocks from complex igneous rocks. She tires of simplicity. She may pour hot lavas over the unconsolidated clays and gravels of the mantle, causing the particles to weld together and new compounds to develop. She may cause hot liquid rock to squeeze between the sheets of sedimentary formations, baking and partially recrystallizing them. She may buckle the surface rocks and profoundly alter the form of all rocks involved. Thus do the metamorphic rocks arise from the alteration of preexisting formations. Intensity of the metamorphic process destroys the characteristic simplicity of sedimentary rocks. Complex silicates grow from the impurities in limestones and dolomites. The grains of sand in sandstones are firmly fused. Shale rocks are converted into aggregates of highly complex silicates.

Metamorphism is fundamentally a process of crystallization and very similar to the process whereby the igneous rocks were originally born from a mother liquid. When sedimentary rocks are subjected to great heat and pressure they are often sufficiently altered as to resemble igneous rocks. Thus the cycle of rock evolution is completed; after many changes the materials of the earth's crust have returned to their original condition. Not once but innumerable times has this round of events been enacted in earth history.

IV

Not only the substance of the earth but also the expressions on her face pass through repeated cycles of change. The concept of erosion cycles is perhaps the greatest contribution of American physiographers to earth science. It has long been known that rivers change the appearance of the lands, but not until comparatively recently has science recognized the orderly cycle of change result-

ing from the long-continued activity of rivers in any given locality.

Streams, like men, pass through stages of infancy, youth, maturity and old age. In infancy a stream is short and steep, and flows in an infant valley, a gully or a ravine. The valley grows longer, wider and deeper with gaining age until youth is reached. The divides between youthful valleys are broad, but the valleys themselves are relatively narrow. The streams flow vigorously, in many cases with waterfalls and rapids. Much of their work lies before them. The country they drain is also youthful because it is destined to be profoundly altered before the streams grow old. With maturity the young streams become longer, their gradients more gentle, their valleys wider. Tributaries increase in size and number to form a branching pattern over the land. The country is reduced from the smooth upland of youth to a group of irregular hills and ridges. With time the gradients of the streams approach nearer and nearer the horizontal, until the water flows in sluggish meanders through low, wide valleys separated by low divides. The streams and the land have grown old.

Like the march of a man from infancy to senility, rivers and the lands they drain do not return to the exact condition of their youth. Although the cycle is not perfect, the old age of a river-carved terrain is remarkably reminiscent of youth. Both are relatively flat and smooth; both are characterized by few main streams and many undrained lakes and marshes. Death never follows old age in the erosion cycle because, before rivers have reduced their lands to sea-level so that marine water can creep in and drown the country, they lose their power to cut away any more material, and turn instead to building up the region which for so long they have labored to destroy. Seldom, in fact, is a region allowed to advance unhesitatingly from infancy to old age, because earth movements continually change the gradients of rivers, steepening and rejuvenating some, flattening and prematurely aging others. Although the cycle is seldom completed, although some parts are repeated and others are eliminated, the tendency to a rotatory sequence of change is present in the rivers and their lands to-day just as it has always been present since the earth possessed an atmosphere to furnish the necessary rain and running water.

V

Not only the substance of the earth and the expression on her face but also the deep-seated changes in her body which control the major events of her history seem to adhere to a cyclical pattern. Even the casual observer of earth features can see that many formations now crumpled and broken were once flat and continuous. Measurements on the rocks of the Alps show a shortening of more than one hundred miles in the earth's circumference. In many other places the circumference has been considerably shortened so that the implication is that the diameter must have likewise been shortened. Such evidence points to a progressive shrinkage of the globe through time. For many years the accepted explanation of this shrinkage was cooling and consequent contraction of the materials constituting the deep interior of the earth. But cooling no longer seems an adequate cause for such a great contraction as is now known to have occurred. Besides, it is not certain that the earth has been cooling. Increasing knowledge of radioactivity has led some scientists to believe that perhaps the earth has actually gained more heat through the disintegration of unstable elements than she has lost through radiation. In the face of modern knowl-

edge the scientist must look to the tremendous pressures in the deep interior as the prime cause of shrinkage. Under these pressures materials may well undergo progressive molecular rearrangements which result in new compounds of greater density and less volume. Thus as age has crept upon her the earth has grown heavier and smaller.

But she does not yield easily to the stresses within her. The study of earthquake waves has shown that the body of the globe is in a state of elastic rigidity, and resists the forces which are ever struggling to decrease her volume. So unrelenting and powerful, however, are the forces of concentration that they periodically overcome the inherent strength of the earth and throw the surface into wrinkles. The yielding of surface formations has proceeded through time in a sort of vicious cycle, epochs of resistance alternating with epochs of surrender. The recognition of this cycle is the basis for the division of recorded time into the geological eras. Each era is set off by a world-wide weakening and yielding of the crust to the stresses of shrinkage. Smaller time divisions are demarked in similar fashion by less intense and less wide-spread convulsions.

The forces of erosion, by leveling lands and filling ocean troughs, have forever striven to reduce the irregularities of the earth's surface to flatness. Earth movements have periodically thwarted erosion by crumpling and elevating rocks in weak zones. Earth history has been a long struggle between these two contenders, the pendulum of success swinging now toward one, now toward the other. Since the earth yields only periodically to the stresses of shrinkage, there are long intervals when erosion can quietly pursue its destructive work. Slowly the rains and the rivers, the winds and the glaciers, remove the rocks from high places and deposit them in the depressions; slowly the spreading seas creep over the lands. If the process were allowed to proceed to its logical finish, the earth would become nearly a perfect sphere and a universal ocean would swallow all the lands. But always before this happens, surface irregularities are renewed by earth movements, if only to be destroyed again by the erosion that always follows. Thus has earth history turned through the eons over a cycle monotonous in its repetition.

VI

In the world of the living with its myriad creatures and their myriad functions, one process dominates and correlates all. That process is nutrition. Eating, growing, reproducing and dying are all that life offers to most plants and animals, and these are merely the means, the results and the failure of nutrition. In the so-called "circulation of matter" we see the most pervasive cycle in animate nature. This cycle may be long and involve many organisms, or it may be short and involve only a few. Long or short, a nutritive cycle of some sort embraces every living creature. Not even death can remove an organism from its fated curve.

Only a few of the many chemical elements in the earth are needed for protoplasm, the basic substance of all living tissue. These chosen materials are forever moving through the bodies of plants and animals. Most plants can take them directly from the soil and the atmosphere, but most animals must steal them from the vegetable kingdom. So it is that plants eat soil and air, animals eat plants, higher animals eat lower animals, whereupon perhaps death intervenes to reverse the order of events. Scavenging lower animals may eat the bodies of the higher animals and regain some of the substance once stolen from their kind. They in turn may die and return the

materials to the dead world of soil and atmosphere whence first they sprang. However long and varied the cycle may be, dust returns to dust and life to life.

Every individual plant and animal passes through a smaller cycle of development during its lifetime. The seed of a tree falls to the ground and begins to germinate. It absorbs moisture, swells and bursts. It sends out roots to anchor itself firmly in the soil and then lifts stem and leaves to the air and the light. Until this stage the young tree lives on the food provided by its parent just as the embryonic mammal lives through its prenatal development.

Soon the plant begins to manufacture its own food with the aid of sunlight, air, soil and the green coloring matter of its stem and leaves. It grows rapidly and passes through seedling and sapling stages until adulthood is reached. These stages are comparable to infancy and adolescence in animals. Both plant and animal are mature when reproduction begins. In the tree reproduction results from the ability to accumulate a reserve of food above its individual needs, so that some of the buds produce flowers instead of leaves. These flowers contain reproductive spores which develop male and female sex cells. Wind or insects effect the fertilization of the female cell, which begins to grow at once until it becomes a seed capsule containing all the essentials for a new tree. Finally the seed, containing food for the hazardous first days of the new life, drops to the ground where it begins its independent existence. Although the cycle is not perfect because return is made to a different seed, the sequence of conditions is a perfect cycle. The offspring seed and all successive stages are identical with the parent seed and its successive stages of development. In some such way has life in all its forms rolled through the ages.

There is abundant indication that the cycle through which the lives of individual organisms are conducted stretches beyond the individual to include the race. Haeckel and Hyatt called attention to the fact that the changes undergone by plants and animals during their early lives are brief summaries of the evolutionary history of the race to which the individual belongs. This idea of recapitulation of biologic history is one of the great generalizations in the science of paleontology.

The racial history of almost any creature has been a vastly longer and more intricate chain of evolving stages than is the life history of even the most complicated individual. Naturally all the events of millions of years can not be summarized during the brief span of one lifetime. Even in the best examples of recapitulation, only a few of the outstanding events are reenacted. In many creatures the racial history is distorted because of the speed with which it must be told in the rapidly growing individual. In six days the oyster presents a résumé of its several million years of racial history. Many stages are necessarily omitted. Then, too, some creatures have been so altered by recent adaptations that their life histories do not give true pictures of the lives of their remote ancestors.

On the whole, however, and in a broad way, developing plants and animals summarize the outstanding events in their evolution. The common frog comes from a fertilized egg which divides and grows into a gill-breathing tadpole. Later the tadpole grows hind legs and fore legs, absorbs his tail and his gills and becomes a mature lung-breathing amphibian. Since these are the rather well-known stages in the evolution of the frog from fish-like ancestors, it is apparent that every living frog, in

the words of Huxley, climbs his ancestral tree.

If the early life of an organism tells the main events in its climb out of the past, does not the later life prophesy the destiny of the race? Are maturity, senility and death the inevitable dénouement for race as well as individual? The paleontologist, who knows some of the secrets of the past, must answer in the affirmative. He sees in the fossil record the rise and fall of races, and he knows that races too have their stages of youth, maturity, old age and death. The only difference is that the racial cycle may be very long, and the individual cycle is usually very short.

The desire to get somewhere is deeply rooted in the human heart, and progress is a word often on the lips of civilized man. But it is a word of numberless meanings because it refers to changes which may seem desirable to some but not to others. The concept of progress is underlain by that other concept of destination. Man wants ends for his struggles, hopes and fears, where he fancies he will find peace. But these are anthropomorphic concepts born of desire. Nature has an entirely different point of view and nature is still the ultimate ruler of her children. In all things which even remotely touch the lives of men she is infinite and timeless. She has imposed a cyclical pattern upon the universe, whereunder all things are charged to go forever, but never to arrive. It avails man little to fret. He had much better travel his curve in the spirit of little children on a merry-go-round, who enjoy the ride though it takes them nowhere.

THE CONFLICT OF SCIENCE AND ART

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We are told that the world is to-day in a transition period and that we must feverishly seek new landmarks along all lines of progress before the old ones vanish completely if they have not already done so. But this is one of those half truths which are too often accepted whole or rejected whole. The joker lies in the fact that in the history of the world each period is a transition period growing out of the one just previous. It is always possible to picture the periods of slow development as transitions between those of great development, but it is much more to our liking, however, to picture the periods of rapid development as transitions between those of lesser progress because man does not like to emphasize the stupidity of the human animal in his more sluggish moments. The fact remains that the future grows out of the past, and no matter how rapid this growth, the old landmarks always have lasted long enough to get us from one period to the next. Indeed, they have often lasted entirely too long.

It took the genius of a Galileo to overthrow the ill-conceived idea of Aristotle that heavy bodies fall faster than lighter ones, an idea which had persisted for nearly twenty centuries. It took the strength of a Martin Luther to overthrow the prevalent church ideal of secular power and reelevate it to a more democratic spiritual level—a thing accomplished, it is interesting to note, by "heresies," which, by the way, are among the most common tools of progress. It took the horrors of a French Revolution to overthrow established modes of government together with dead classical artistic and literary forms which had been outgrown, and even to-day civilization carries a staggering burden of superstition and dogma which, much as it has been reduced in the last few decades, will persist entirely too long.

It can scarcely be expected that good business principles be applied to realms as strongly tinged with emotion and sentiment as art and religion. Good business demands that when a thing is worn out it be cast aside in the interest of efficient management. Sentiment and emotion often demand that it be blindly clung to long after its usefulness is past.

The head of a large new electrical plant recently stated that in exactly seven years the machinery and methods of operation in his plant would be obsolete. This is a shock to the imagination because most people have an inborn preference for long life periods. A man likes to imagine his political party remaining in power indefinitely, his lawnmower lasting him the rest of his life and his favorite brand of cigars retaining an even and unvarying flavor. He even likes to think of some permanency within himself which indefinitely survives death and decay. However this may be, the world owes Bergson, following Heraclitus of old, a generous debt for putting emphasis on the dynamic rather than the static side of life, upon the fact that life itself is a process of never-ceasing change, and the truth of such a concept is growing increasingly apparent.

Though to the average man any variations of his daily routine are usually annoying irritations, of late he has indeed come to accept some of these fluctuations and disturbances as necessary evils. The automobile with its

many uncertainties has helped in the conversion. However, the automobile is a product of physical science, and it is largely due to the sweeping progress of physical science, and to a slightly lesser degree biological science, that the world of to-day owes its recognition of the continual flux of life and also owes the attendant intellectual unrest which is felt in the field of art no less than elsewhere, and has even spread its influence to those realms of greatest inertia, the moral and the religious.

The sciences have thrown down the gauntlet to the rest of the world in the matter of intellectual house-cleaning and in the rapid replacement not only of worn parts but worn ideas and dogmas. This itself is in no essential conflict with the world of art. Art has always tried to be progressive even in its weaker moments, but progress in art is made with less of surety than in science—witness, for example, the empty technical embellishments which followed the Renaissance, the Pre-Raphaelite movement which sought to make progress forward by turning backward and trying to recapture the outlook of the primitive, or witness the meaningless vagaries of some of the extremists of our own unesthetic era. The conflict lies in the fact that science progresses by logic while art does not. Once a law of nature is formulated it is tested by the deductive method of Aristotle's syllogism, but no syllogistic test of its basic merits could have determined that Boston should refuse the Dancing Bacchante of MacMonnies or that Barnard's Lincoln was too realistic for London. A work of art does not submit itself to the syllogism.

To go back to the time of Leonardo da Vinci, one sees a great artist and a great scientist combined in one. The strength of his delineation of the human body was due partly to his scientific study of anatomy, but anatomy was then a new field. There were no treatises on anatomy for art students as there are to-day, and to-day few art students would perhaps care to study over such human corpses as did Leonardo. Art and science in a very real sense have parted company since the time of Leonardo, and there are perhaps none to-day who can qualify both as great artists and great scientists at the same time. But this does not mean in the least that an inseparable wall has grown up between the two. There is more science in art to-day than ever before and likewise more art in science. The high level of modern individual specialization bars the way of even the superman to equal achievement in each, but it was never easier in the history of the world to borrow and lend ideas between them. When the early Italian painter mixed his colors he was his own chemist. When Benvenuto Cellini in desperation reduced the melting-point of the molten metal for his Perseus by casting in his pewter dishes he was acting as his own physicist. But to-day the rich wealth of materials and technical skill of any field is open to any other. Science and art have parted company not in the sense of the interchange of ideas but because they represent two distinct types of specialization, distinct in subject-matter and distinct in method.

Physical science in particular has risen to such a pinnacle that its methods and many of its results, even, can be understood only by the man especially trained to understand the mathematical symbols involved, as for example, the recent Einstein theory of relativity. The average college graduate is little better off in trying to fathom these Einsteinian abstrusities without first learning the language involved than a Sioux Indian trying to communicate with Mars. Only in such instances as the invention of the radio are the results of abstract science made generally intel-

ligible because of the intimate contact with daily life, and even then the god of the machine is usually a dark mystery. Fortunately it is not necessary to serve an apprenticeship in an electrical laboratory in order to use a radio profitably, nor is it necessary to know all about the technical background of implements and methods in order to appreciate a finished sculpture or painting. The single necessary condition is that both make intimate and direct contacts with life. No matter how these contacts are achieved they must be present, and the fact that in science they are achieved in a roundabout way by means of a complicated symbolism is no reason at all why they should or could be obtained in art by the same method.

The recent tendency toward an extreme symbolism in art is an unfortunate appropriation from the realm of physical science. The symbolism of early Christian art, which developed from a set of secret symbols used to protect Christian worshipers, is another matter. In later Christian art symbols were more artificially formed, as, for instance, the rules established by the Spaniard Pacheco sometime after the year 1617 for the representation of the Immaculate Conception with the Virgin clad in white with hands folded, crowned with a ring of twelve stars about her head, and standing above the moon whose prongs were supposed to be turned downward. But such symbols came to represent a common language. When expressionists, futurists or what-nots make use of a strange and unfamiliar symbolism they defeat their own aims, if perchance they have aims other than the complete mystification of the public and the hoodwinking of a few of the more gullible critics. To understand such a production one must be versed in the artist's own *individual* symbolism, not as in the case of physical science in a *uniform* mathematical symbolism common to students everywhere in all countries. But is this the aim of art? And what is there to keep such an individual symbolism from running wild? Near the Canadian border it may or may not be a violation of law to take a drink of liquor, but two times two is four no matter where one stands. The laws of mathematics are universal, and likewise art in its larger aspects must attempt to surmount the petty boundaries of race or nation and achieve universal stability.

To deny the extremes of symbolism to art is not in the least to restrain its free development. The Copernican theory that the earth revolves about the sun, one of the most revolutionary and epoch-making theories in history, had its inception in the careful mathematical analysis of observed data. The symbolism involved prevented the immediate and complete acceptance of such a theory for the multitude, but in the universality of such symbolism lay the strength of the theory and the promise of its final acceptance. On the other hand, little more than a century ago, the great forward movement of romanticism in painting was initiated by Gericault with his Raft of the Medusa, which broke away from impotent classicism and revealed life in its passion and suffering. Direct and intimate contact with life was reestablished by Gericault not by means of abstract symbols but over the suffering bodies of the survivors of the Medusa.

More and more complicated types of mathematical symbolism are necessary to deal with the growing and universal complexities of the physical world, but art, on the other hand, has enjoyed no such sudden and tremendous logical expansion, nor will it ever. Progressive in spirit as art must be, to retain its vitality and its influence on life, nevertheless the parallel with science ceases there, because at the same time art to retain its influence must retain its con-

tacts directly with life without the impassable barrier of a complicated symbolism. The dominance of scientific method in life to-day need not permit it to overwhelm the realm of art. The unlearned person who says of an extremist creation, "I can make nothing out of it," is sometimes nearer right than the enthusiastic critic who is carried away by his own imagination and ecstatically exclaims, "Isn't it a glorious departure from tradition!"

What is true and what is false in art and science are determined in different ways, and yet there is a fundamental underlying relation. At bottom the true test of anything is the acid test of time, and that is nothing more than the pragmatic judgment of results. Science with its mathematics may project itself far into the future and wait centuries perhaps for its final justification, but art is of necessity tied more closely to the present.

Science in its development may so far outstretch the intellectual training of the multitude that only the few can follow it with all-seeing eyes and help push its boundaries forward. It is the province of the few, and only in its useful results can such a position be justified; but with art it is different. The emotions are more elemental than the logical processes. The logical structure of intellect is built slowly step by step and theorem by theorem, but the emotions are trained in no such axiomatic manner. They are the sources of impulse and imaginative longing which it is the duty of the intellect to guide and temper. Art can never outstrip the emotional level of the race as science does the intellectual level because it is not logical. It can blaze a trail, but it can not establish a petty kingdom of its own without defeating its own ends.

Passing over the arguments of the theorists as to wherein lies the beauty of a work of art, Tolstoi was certainly fundamentally right in asserting that great art must be directly intelligible, in part at least, and Bendetto Croce was certainly fundamentally wrong in stating that art is ruled uniquely by the imagination. One might as well say that philosophy and religion are ruled uniquely by the imagination because they attempt to transcend common facts and interpret them to us. Indeed, even physical science attempts to transcend the common facts of experience to a certain degree, but it is certainly not ruled uniquely by the imagination. The creative imagination may be the handmaiden of the arts and philosophy more than of science, but it by no means rules the intellect. Man is primarily a reasoning animal, and mental images untempered by intellect may have as little meaning as a cubist picture of snow in July. Croce's dictum must be interpreted to indicate a rational mental function and to exclude all such possible imaginative jumbles as that which has recently defined art as a color-form-time rhythm in three dimensicns in which all natural representation is nugatory.

It is true that the emotions themselves are non-rational, and therein lies the real conflict between art and science. Struggle as each may to absorb values from the other there is always a yawning gulf between. Science painstakingly analyzes and finds a common denominator, while art painfully attempts to analyze and find a common denominator with little success. Emotion is a personal matter. It may have universal aspects but it can not be written in a mathematical equation. Mr. Clive Bell would reduce art to "significant form," Mr. Croce to intuition, but who is better able than before to judge the true and the false? Of course art must continually attempt to rationalize itself, and in spite of the gulf between art and science, art must copy scientific method in the judgment of values as far as it possibly

can; but there are limits to this process. The elements common to both science and art together with their limitations deserve to be better understood.

The average artist would hear with surprise or perhaps alarm that he is being influenced particularly by that at once terrifying and intriguing branch of mathematics known as the four-dimensional geometry of Lobachevski and Riemann. Nevertheless, it is true, for this four-dimensional geometry of the mathematicians has broken down the last stronghold of the absolutists who conceived that the standards by which we judge the true and the false are absolute rather than relative. The relativists have won. True and false are relative terms, and the standards of judgment of art must be relative, flexible and progressive; not absolute, rigid or static. Never again may art be ruled by an absolute dictum such as the classicism of the pre-revolutionary period in France.

The emotional content of a picture is for the most part directly appreciated, but the fact content of a scientific law is appreciated only by a more or less involved reasoning process. At the risk of oversimplification of the age-long problem of what constitutes a work of art it may be said that the answer lies in whether the emphasis be on one or the other of these two processes. But these processes are never wholly separate. The arts have their formulas, especially music, the most formal of them all, and the sciences have their share of the emotional content too often overlooked by the outsider who speaks of the "cold, hard, facts of science." The emotional response of a Newton formulating a law of universal gravitation or of an Einstein illuminating the earlier views of Newton with his own searching revelations of the relativity of all things must not be minimized. At any rate, the results of modern science affecting man in his every action can have no other interpretation than in terms of warm, pulsating human values. Wide as the gulf may be between art and science, it narrows perceptibly when it is realized how inseparable thought and feeling are, and that neither must be allowed to run amuck, without the tempering influence of the other.

Science running wild may lead to a war beside which the horrors of past wars are insignificant. Already there are rumors of secret poison gases many times more poisonous than those of the recent past which may easily destroy whole cities, perhaps nations. It has become a truism that the war of the future will be between cities and nations, not armies, and that more than ever before it will be waged unto the death of all even remotely concerned. On the other hand, it is not at all impossible for peace-time science to run wild and build up a staggering industrial mechanism that might crush its adherents. The consequences of art running astray which have been visible in some recent exhibits are more insidious but nevertheless real and indicative of racial decadence.

Whether art be defined in terms of beauty or pleasure or valuable experience, in the last analysis the appreciation of its values must depend upon the experience of the individual, and that means that thought must accompany feeling. Perhaps in music of all the arts the thoughts are the most vague and least expressible by words, and yet the enjoyment of a symphony depends largely upon the listener's previous experience which determines the thoughts that accompany his emotional states. In other words, it is impossible to sit through a symphony with a perfectly blank mind.

A picture by Renoir may be interesting for its colors, a work of Michelangelo for the modeling it displays, an early Egyptian decoration for the story

it tells, a Corot for the mood it exudes, an extremist creation for the unrestrained movement of color—there are different values in different pictures—but beware of that modernist who tells you that his picture has nothing to do with anything you are familiar with, that it has no connotative interest and that it is to be enjoyed only as it affects the emotions. Somewhere in the picture if it is sane there must be thought. If the forms are not recognizable, the colors at least must be. The artist overvalues his own response to the picture, but somehow or other there must be sufficient thought, sufficient organization so that his response is transferred in part to his opticence, else there is no real art.

Out of a group of mathematical equations proposed by J. Clerk Maxwell in 1885 and understood by only a very few at that time came the discovery of electromagnetic waves and the invention of the radio telephone. Thus did the apparently "cold" science of Maxwell find its ample justification in the everyday life of the common man. The radio, which brings us human voices out of a seemingly empty space and has tied together the men and minds of many lands, has endowed those seemingly dry and abstract equations of Maxwell with human values even now pulsating from station to station around the world. The romance of science is no fiction; it is the romance of to-day and to-morrow, and where there is romance there must be emotion. Out of the Einstein theory came the explanation of the discrepancy in the calculation of the orbit of the planet Mercury, and again practical justification is achieved. It takes no more abstruse mathematical training to appreciate these results than it does to appreciate the fact of a Moses by Michelangelo, but the appalling abstractions back of the former are wont to mislead many a well-meaning enthusiast who imagines that they represent pure intellect without emotion, and that conversely *he* may sail on the wings of emotion into the ethereal realm of art, leaving intellect behind. Like Icarus he falls to his death with the realization that his wings were willing but the wax was weak. Emotions can not fly high unless secured by tempering thoughts any more than intellect can ignore the emotions.

When science tries to record phenomena it exercises its imitative function to a high degree. The length of the standard meter in Paris may be imitated to within at least a few parts in ten million. The modern theory of the atom built up of electrons rotating about a central nucleus like a tiny solar system was an attempt at a very exact imitation of that reality which the scientist believed to exist. Again, a photograph very closely imitates the landscape which it copies. It does not become a work of art until certain definite values are brought into emphasis, and then blind imitation ceases. Ruskin in one of his moments of misapprehension decried the so-called "blurs" of Corot. The evanescent tracery of those well-known trees disagreed with his preconceived notion that art should consist of a more precise imitation of reality, but the judgment of the years has vindicated Corot. It is the business of the artist to create impressions, and it is the business of science to create reproductions. All art is impressionistic in this sense.

On the other hand, as in the case of the famous "flying gallop," science exercises a restraining function to prevent a too wide departure from truth. In 1880 the camera was used to prove that no horse ever did or could assume such a position with legs extended and all four feet in air as was depicted in the flying gallop of Gericault and his followers. Only since such impressionism was recognized as inadequate has it come to be supplanted, not necessarily by any of the exact positions shown by the camera

itself, but by a higher and more truthful type of impressionism.

And so it is that art and science though fundamentally antagonistic to each other yet have much in common and even in their antagonism serve to balance and restrain one another. As great a romanticist as the late Arthur B. Davies considered that he owed much to his early engineering training. The conflict of science and art is real, but it is necessary, for when there is no conflict there is no stimulus to achievement and there can be no progress. It has been so in the apparent conflict of science and religion in spite of the rowdyism aroused. At bottom the various activities of man support each other, and one of the most striking points in the general development of ideas in history has been the way in which similar motifs have appeared in parallel lines of thought and endeavor. Often it is difficult or impossible to assign priority to any field and to tell from which the greatest influence has spread, and yet it may be stated in entire safety that the sweeping and fundamental character of the development of physical science has profoundly influenced every other realm of human activity. The back-to-nature movement of Copernicus, Galileo and Newton in which natural phenomena were taken at their face value by direct experiment was closely paralleled by the back-to-human-nature movement of Shakespeare and Michelangelo. It was the golden age of naturalism in art, letters and science whose perpetuating influence is with us to-day, tempered only by movements within movements which have grown up since then.

In the last century the positivism of science which began to accept the view that knowledge of the world we live in is limited to those messages brought to the brain through the gateways of the five senses found its counterpart in the impressionism of Manet and Monet and the emphasis put on the value of light and color. To the impressionist the real world is not directly known to the observer but his impressions of it are brought to him through the sense of sight by the penetrating movement of light and color. The attitude of the scientists had reappeared in the pictures of the impressionists and the emphasis on the new meaning of light and color came as the most important contribution of the nineteenth century to art. What the twentieth century may hold can not even be guessed. In the past few years the study of light has revealed more about the nature of things to the scientists than any other study. In art a similar emphasis has been put on light and color, and in forgetting about exact imitations these impressionists and luminists have often disclosed more about the eternal significance of things than any of their predecessors. To-day the theories of relativity and quanta are profoundly influencing scientific and philosophic thought, and we may confidently expect art as the counterpart of science to reflect the spirit of these movements, but let us not expect art to answer in the same language and with the same tongue.

MALTHUS, A REVALUATION

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EVERY entirely human being has a well-spring of sympathy for the Athenian citizen who said that he was going to vote for the other candidate because he was tired of hearing Aristides called "the just." Nearly every one who is compelled to listen to an optimist or who finds himself unwittingly reading one has feelings akin to those of that disillusioned citizen of ancient Athens. To sensitive persons, perhaps the sweetest of sports is the puncturing of optimists: Malthus was of that gentle strain.

William Godwin, author of the "Enquirer," while perhaps not the most abominable of optimists, was certainly a fully developed adult member of the species. Let the reader judge from a page of Godwin's "Political Justice." We find a paragraph to the effect that the time may come when we shall be so full of life that we need not sleep and so full of living that we need not die; the need of marriage will be superseded by the diversion of developing the intellect; we shall be as angels. And then: "Other improvements may be expected to keep pace with those of health and longevity. There will be no war, no crimes, no administration of justice, as it is called, and no government. Besides this, there will be neither disease, anguish, melancholy nor resentment. Every man will seek with ineffable ardour the good of all."[1] It was a—perhaps unworthy—desire to puncture this gorgeous bubble that brought forth, in 1798, Malthus' first essay on "The Principle of Population."[2]

A modest country parson, Malthus called down upon his head a stream of vituperation sufficient to sink a navy. Nevertheless, it did not occur to those who contributed to this torrent of abuse that a fire which could not be put out with a smaller stream must be the very fire of truth itself. This quiet rural scholar and parson was accused of defending smallpox, slavery and child-murder; of denouncing soup-kitchens, early marriage and parish allowances; of having the impudence to marry after preaching against the evil of families; of thinking the world so badly governed that the best actions do the most harm—in fine, of taking from life all its joys and virtues.[3]

Thomas Robert Malthus was the son of a radically inclined English country gentleman, who was the friend of Rousseau and executor of his estate: Daniel Malthus was—rarest of creatures—a gentle optimist, nevertheless an admirer of that rampant optimist, William Godwin. The Malthuses, father and son, were fond of polemics, and, by the fireside or while taking walks, often had a friendly bout of argument. When Godwin brought out the "Enquirer" in 1797, the debate blazed up. Robert, as he was most frequently called, affirming as great a love for humanity as ever his father had—or Godwin or Rousseau or Condorcet—protested that he could not acquire "that command over his understanding which would enable him to believe what he wished, without evidence, or to refuse his assent to what might be unpleasing when accompanied with evidence."[4] He was what the American

[1] William Godwin, "Political Justice," Book viii, ch. ix, p. 528.

[2] Ford K. Brown, "Life of William Godwin," London, 1926, p. 124.

[3] *Edinburgh Review*, Vol. 64, Article IX, January, 1837.

[4] T. R. Malthus, "The Principle of Population," preface to first edition, London, 1798.

philosopher, William James, called tough-minded, in contradistinction to tender-minded, the quality of being convinced by words grammatically and rhetorically expressed regardless of import. So he opposed vigorously the parental view, impregnated with the lofty philosophy of Rousseau, Condorcet, Godwin and Company.

Being of a serious and economical turn of mind, to see his carefully worked out and earnestly expressed ideas disappear into thin air was distasteful, so he wrote:

> The following Essay owes its origin to a conversation with a friend, on the subject of Mr. Godwin's Essay, on avarice and profusion, in his "Enquirer." The discussion started the general question of the future improvement of society; and the Author at first sat down with an intention of merely stating his thoughts to his friend, upon paper, in a clearer manner than he thought he could do, in conversation. But as the subject opened upon him, some ideas occurred, which he did not recollect to have met with before; and as he conceived, that every, the least light, on a topic so generally interesting, might be received with candour, he determined to put his thoughts in a form for publication.[5]

The full title of the thesis which followed was, "An Essay on the Principle of Population as it Affects the Future Improvement of Society, with Remarks on the Speculation of Mr. Godwin, M. Condorcet and Other Writers."

The essay was published anonymously. It was instantly recognized as a significant piece of writing.[6] Enemies attacked it only with their stoutest cudgels. Friends found it quite capable of defending itself. William Pitt, the prime minister, paid it the rarest if not the greatest compliment a piece of philosophy has ever received: he put its principle immediately into political practice; he dropped his bill to amend the Poor Law.

At this notable reception no one was so surprised as Malthus himself. He busied about trying to find how much there really was in this principle of population which he had so cursorily pronounced. To his astonishment he found that much had been written upon the subject.[7] Bashfully he inserts in the preface of the second edition (referring of course to the first essay):

> It was written on the spur of the occasion, and from the few materials which were then within my reach in a country situation. The only authors from whose writings I had deduced the principle, which formed the main argument of the essay, were Hume, Wallace, Dr. Adam Smith and Dr. Price.

Then further on:

> The more I considered the subject in this point of view, the more importance it seemed to acquire; and this consideration, joined to the degree of publick attention which the essay excited, determined me to turn my leisure reading towards an historical examination of the effects of the principle of population on the past and present state of society. . . . In the course of this inquiry, I found that much more had been done than I had been aware of when I first published the essay. The poverty and misery arising from a too rapid increase of population had been distinctly seen, and the most violent remedies proposed, so long ago as the times of Plato and Aristotle. And of late years the subject has been treated in such a manner, by some of the French Economists, occasionally by Montesquieu, and, among our own writers, by Dr. Franklin, Sir James Steuart, Mr. Arthur Young, and Mr. Townsend, as to create a natural surprise, that it had not excited more of the publick attention.[8]

But the Reverend Malthus was not backing water; he knew the battle was not his but the Lord's: "The main principle advanced is so incontrovertible, that, if I had confined myself merely to general views, I could have entrenched myself in an impregnable fortress, and the work in this form would probably have had a much more masterly air."[9]

[5] *Ibid.*

[6] *Quarterly Review*, 17: 375, note, July, 1817. L. H. Haney, "History of Economic Thought," p. 231, New York, 1924.

[7] Haney, *op. cit.*, p. 230.

[8] T. R. Malthus, "The Principle of Population," preface to second edition, London, 1803.

[9] *Ibid.*

We have said that recognition of his work was immediate: execration, abuse and refutation appeared quite as promptly, and they poured down upon Malthus and his principle for thirty years. The discussion has never simmered out, and there are present signs of considerable future conflict.

Six editions of the essay were published during Malthus' lifetime. Between the first and second editions there were more than a score of formal replies. Discussion appeared also in public journals, and in parliamentary debate, but—as with many great and astonishing books—it seemed that almost no one read it. Even N. W. Senior, England's most distinguished economist of his day, confessed that he trusted more to his ears than to his eyes for a knowledge of the Malthusian principle, though he had written a learned dissertation upon the followers and critics of Malthus.[10] The *Edinburgh Review, or Critical Journal,* for April, 1810, August, 1810, says, "The excellent work of Mr. Malthus, though it has certainly produced a great and salutary impression on the public mind, appears to us to have been much more generally talked of than read, and more generally read than understood."[11]

Like every popular conflict, however fundamental or simple, the Malthusian controversy has been hopelessly muddled from the very beginning. Early critics and opponents of Malthus, after the manner of popular critics, attacked not his main proposition but some of the consequences which they saw flowing from it. Some were led even so far away from serious discussion and sound science as to put into practice the immemorial first axiom of jury lawyers: When you have no case, abuse the plaintiff's attorney—and in this case Malthus was his own attorney. Cobbett made himself prominent among early critics by inventing the sobriquet "Parson" Malthus. It occurs in the following passage in which Cobbett addresses a young farmer:

> "Why," said I, "how many children do you reckon to have had at last?"
>
> "I do not care how many," said the man, "God never sends mouths without sending meat."
>
> "Did you never hear," said I, "of one Parson Malthus?"
>
> "No, sir."
>
> "If he were to hear of your words, he would be outrageous, for he wants an Act of Parliament to prevent poor people from marrying young, and from having such lots of children."
>
> "Oh, the brute," exclaimed the wife, while the husband laughed, thinking I was joking.[12]

There was, however, one capital misunderstanding—one that, apparently, existed even in the mind of Malthus himself. The Malthusian theory, as viewed through a vista of one hundred and forty years, and in the light of subsequent developments in economic and biologic sciences, is not a theory of population but a theory of poverty. Adam Smith produced a great work on the theory of wealth: twenty-two years later, T. R. Malthus uttered a brief essay—even more powerful in shaping human thought and affairs—which was a theory of poverty. One need not marvel, however, that the author of a significant piece of scientific work can mistake its fundamental meaning, for, if uncommon, it is not unheard of. Did not the revolutionary Darwin persist to the day of his death in calling his great book the "Origin of Species"? Biologists everywhere accept Darwin's "Origin of Species" almost *in toto* as a hypothesis, or as a theory, of biologic progress; but an increasing number of first-rate biologists reject it as an adequate explanation of the origin of species.

Malthus did not explain the cause and manner of population growth and de-

[10] J. Bonar, "Malthus and His Work," New York, 1924.

[11] 16: 465.

[12] Quoted by Leslie Stephen, "English Utilitarians," Vol. ii, p. 255.

cline. By his central proposition, overpropagation, he brought to light, however, the unmistakable, the sovereign explanation of why poverty exists and always has existed.

No superficial reading or hearsay evidence of the thoughts of Malthus reveals his central proposition—as is clearly shown even in recent criticism, for the overwhelming majority of anti-Malthusians attack his statement that population increases in geometric ratio while the supply of human aliment increases in arithmetic ratio. Malthus said just that, and he stuck to it through six editions, but it is far from being the central meaning of his great essay. No one who has read him through the six editions, published during his lifetime, or even through the pivotal first, second and sixth editions, could possibly mistake the essential and surviving meaning of his work: Life everywhere and always tends to exceed the warrant for it. Wallace did not mistake this matter, nor did Darwin; and it is rather too bad that the perspicacity of recent students has not been capable of penetrating this extremely perspicuous book.

Speaking of "The Principle of Population," Wallace says,

> It was the first work I had yet read treating any of the problems of philosophical biology, and its main principles remained with me as a permanent possession, and twenty years later gave me the long-sought clue to the effective agent in the evolution of organic species.[13]

Darwin writes,

> In October, 1838, that is fifteen months after I had begun my systematic enquiry, I happened to read for amusement Malthus on population, and being well prepared to appreciate the struggle for existence which everywhere goes on . . . it at once struck me that under these circumstances favorable variations would tend to be preserved and unfavorable ones to be destroyed. The result of this would be the formation of a new species. Here then I had at last got a theory by which to work.[14]

Both Wallace and Darwin saw clearly the framework of the evolutionary theory of biologic progress, a matter of heredity and variation; but the key factor, the dynamic factor, overpropagation, without which their scheme was inert and meaningless, that, they both testify, was cabbaged from Malthus.

In the eighteenth century a little preliminary bowing and scraping was necessary before anything from tea squalls to treason could fairly be undertaken. The first edition of Malthus' essay starts out,

> I think I may fairly make two postulata: First, That food is necessary to the existence of man. Secondly, That the passion between sexes is necessary, and will remain nearly in its present state.[15]

These are propositions which, for historical reaches of time, even the most critical will admit as axioms. They do not, however, necessarily produce the proposition which Malthus brings forward as his second siege gun:

> Assuming, then, my postulata as granted, I say, that the power of population is indefinitely greater than the power in the earth to produce subsistence for man.[16]

Then comes the joy and delight of captious critics, the straw man which they hurl to the flames, and call it scorching Malthus:

> Population, when unchecked, increases in a geometrical ratio. Subsistence only increases in an arithmetical ratio. A slight acquaintance with numbers will show the immensity of the first power in comparison of the second.[17]

[13] Alfred Russell Wallace, "My Life," Vol. I, p. 232.

[14] Charles Darwin, quoted in "Life and Letters," edited by Francis Darwin.

[15] T. R. Malthus, "The Principle of Population" (parallel chapters from the first and second editions, p. 6, the Macmillan Company, New York, 1923).

[16] *Op. cit.*, p. 7.

[17] *Op. cit.*, p. 7.

Now having fired what he thought were his three big guns, but which even his most loving friends to-day know were but bursting paper bags, he utters a statement which brought to a majority of intelligent human beings an entirely new way of looking at life:

> Through the animal and vegetable kingdoms, nature has scattered the seeds of life abroad with the most profuse and liberal hand. She has been comparatively sparing in the room, and the nourishment necessary to rear them. The germs of existence contained in this spot of earth, with ample food, and ample room to expand in, would fill millions of worlds in the course of a few thousand years. Necessity, that imperious, all-pervading law of nature, restrains them within the prescribed bounds. The race of plants and the race of animals shrink under this great restrictive law. And the race of man can not, by any efforts of reason, escape from it. Among plants and animals its effects are waste of seed, sickness, and premature death. Among mankind, misery and vice.[18]

This, reduced to simplest terms, is the essential Malthusian proposition. This is the spark of living fire which set Wallace and Darwin aglow to light less penetrating minds through the labyrinthic bio-universe. Reducing this statement to a minimum—even at the risk of bungling—it runs: Life everywhere and always tends to exceed the warrant for it, with consequent universal suffering and destruction. Any one who refutes this, refutes Malthus; persons attacking the essay at any other point are merely wasting paper and printer's ink. (Malthus said a great deal more, much of it entirely without substance, but if the strongest, soundest mind that ever wrestled with life's riddles were implanted in the most facile wordsmith who ever sucked a pen, this ideal writer would produce much that the feeblest critic could quote against him six generations later.)

The next step in Malthus' reasoning is along the path of clear logic. If population everywhere and always tends to exceed the warrant for it, there must be constant checks upon its growth. He then goes through the motions of discovering these "checks" and naming them. The "ultimate check" is the scarcity of food; in general, however, this check is seldom reached. The "immediate checks" are diseases and harmful customs, resulting directly and indirectly from food shortage. These "immediate checks" fall into two groups, "positive" and "preventive." The positive checks are unwholesome occupations, severe labor, extreme poverty, diseases, bad nursing, war, plague and famine. The preventive checks are moral restraint and vice.

In his thoroughgoing book on "Malthus and His Work," James Bonar develops the Malthusian thesis in a way that does not in the slightest preclude the outline just given: Bonar finds that Malthus, despairing of mastering all forms of evil, confines his study to one, the tendency of living beings to increase beyond the available food supply. He then goes on to show how under Malthus' treatment this apparently simple idea, overpropagation, becomes two collateral propositions. In the case of plants and animals, reason does not come into play; new lives are crowded into the world only to be wiped out by starvation. The struggle is for room and food. An individual survives only through ability to crowd his fellows into oblivion. But man is more happily endowed: the instinct for reproduction is equally strong, but he does not blindly follow it. He asks himself whether he may not be bringing into the world beings for whom he can not provide. If he sweeps reason aside, he tends to increase his numbers beyond the means of subsistence, and his numbers must be cut down to those limits by suffering and starvation.

Throughout his interpretation, Bonar keeps to the moral plane on which Godwin and Malthus wrote their essays. Whether this is because Bonar loses him-

[18] *Op. cit.*, pp. 7–8.

self completely in his work and, like the good actor, lets the characters speak through his lips, or whether he himself feels the problem of population to be chiefly a moral issue, it is not easy to say. However that may be, he spends a great many words and apparently much effort to show that Malthus did not hold ideas "contrary to the notion of a benevolent providence." It is not difficult, however, to boil off the fine ether of moralizing and to retain simply the palpable, ponderable portions of Bonar's accurate, well-joined summary of the Malthus thesis.

An interesting explanation of the mathematical language in which Malthus expressed his principal thesis is offered by Bonar: Malthus maintains that population increases by itself, but food is increased by an agency external to it, the human beings that want it. Moreover, eating is instinctive, but not the getting of the food. We have, therefore, to compare an increase due to an instinctive desire with an increase due to labor, and a "slight comparison will show the immensity of the first power over the second."[19] Malthus then admits the difficulty of determining the relationship with exactness; but, "with the natural liking of a Cambridge man for a mathematical simile," he says that the one is to the other as an arithmetical is to geometrical ratio, that is to say, over any given period of time, population increases by multiplication, food only by addition.

Bonar then goes on to show how Malthus finally leaned away from the mathematical statement of his principal thesis, asserting in the end that *all* forms of life tend to increase in geometrical ratio —in the MacVey Napier Supplement to the Encyclopaedia Britannica (1824). In that publication, Malthus left his mature statement of cardinal principles:

(1) That all living things, of whatever kind, when furnished with their proper nourishment tend to increase in a geometrical ratio, whether (as wheat) by multiplying sixfold in one year, or (as sheep) by doubling their numbers in two years, tending to fill the earth, the one in fourteen, the other in seventy-six years. But (2) as a matter of fact they do not so increase, and the reason is either man's want of will or man's want of power to provide them their proper soil or pasture. The actual rate of increase is extremely slow, while the power of increase is prodigious. (3) Physically man is as the rest; and if we ask what is the factor of his geometrical increase, we can only tell it, as in the case of wheat and sheep, by experience. (4) In the case of other living beings, where there are most room and food there is greatest increase.

Malthus then goes on to show (still in the MacVey Napier Supplement) that human population could easily double every twenty-five years, but admitting that improvements and extensions in agriculture would add largely to the supply of food—admitting even that Godwin's communism might improve matters —these additions to the food supply would be gained at a constantly increasing expenditure of human effort. Inequalities in the distribution of wealth, furthermore, can check the efficacy of an increasing food supply quite as definitely as though that increase were lacking. The main point, however, is the diminishing productiveness of effort applied to the production of food. Summing up, he says, "It follows necessarily that the average rate of the actual increase of population over the greatest part of the globe, obeying the same law as the increase of food, must be totally of a different character from the rate at which it would increase if unchecked."[20]

According, then, to his one great interpreter, James Bonar—and according to all his discerning disciples—Malthus makes the actual increase of population depend upon the difficulty (or ease) of getting food.

To sum up, there were six editions of

[19] Here Bonar is quoting Malthus, "The Principle of Population" (second edition), p. 5, London, 1803.

[20] *Ibid.*

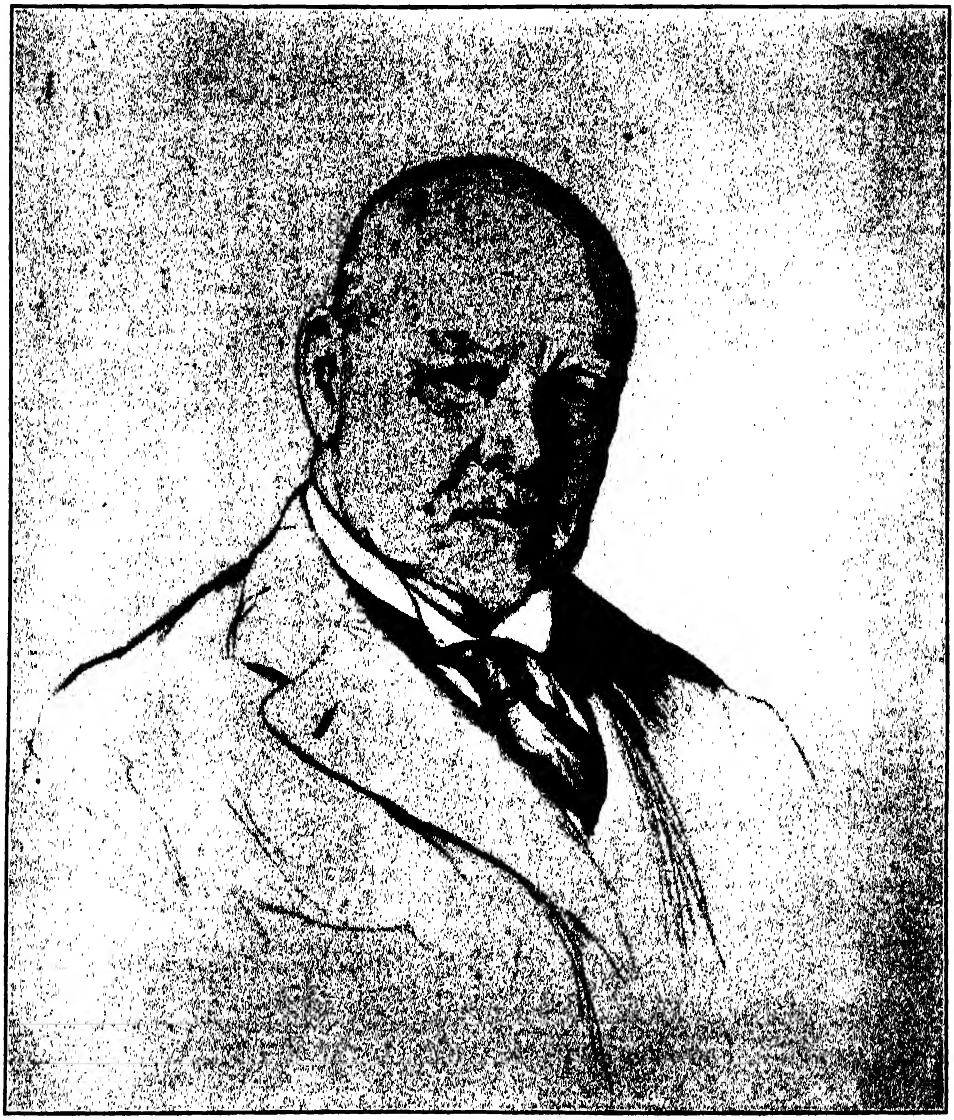
Malthus' essay on "The Principle of Population" during his lifetime, the first in 1798, the last in 1816; a seventh edition was published posthumously; but more important is the article in the MacVey Napier Supplement to the 1824 Encyclopaedia Britannica. It is an authoritative epitome of the author's doctrines in their final form. The "Summary View of the Principle of Population" (1830) was merely an abridgment of the encyclopedia article.

A quantitative analysis of the sixth edition brings out a curious turn of mind on the part of Malthus. Two hundred and fifty-three pages are devoted to the "checks to population"—which seemed to enthrall Malthus—whereas he requires only seven pages in which to develop his main thesis, as it is read to-day and as Wallace and Darwin appropriated it in developing the evolutionary hypothesis of biologic progress.

Properly understood, the Malthus essay, then, is not an essay on population but an essay on poverty. The author does not explain the cause and manner of population growth, but he does establish convincingly the chief cause of poverty and misery. The central thesis of his essay is not that population increases in geometrical ratio while food increases in arithmetical ratio: its central thesis is that life everywhere and always tends to "increase beyond the nourishment prepared for it."[21] Or, speaking of human beings, "Population has this constant tendency to increase beyond the means of subsistence."[22]

[21] Sixth edition, p. 2.

[22] *Op. cit.*, p. 3.



DR. WILLIAM H. WELCH

DRYPOINT PORTRAIT BY ALFRED HUTTY, PRESENTED TO DR. WELCH, AND BY RADIO TO SOME FORTY INSTITUTIONS THROUGHOUT THE WORLD, ON THE OCCASION OF HIS EIGHTIETH BIRTHDAY, APRIL 8.

THE PROGRESS OF SCIENCE

IN HONOR OF DR. WELCH[1]

The many years that I have been honored with Dr. Welch's friendship make it a privilege to join in this day of tribute to him by his friends and by the great scientific societies of our country and the whole world. Dr. Welch has reached his eightieth year and a whole nation joins in good wishes to him.

Dr. Welch is our greatest statesman in the field of public health, and his public service to the nation well warrants our appreciation of him. With profound knowledge, wide experience and skill in dealing with men, sound judgment and a vision of the future, he has been a great asset to the nation, and we may fortunately hope that he will continue for many years more to bless mankind with his invaluable leadership.

Our age is marked by two tendencies, the democratic and the scientific. In Dr. Welch and his work we find an expression of the best in both tendencies. He not only represents the spirit of pure science but constantly sees and seizes opportunities to direct its results into service of humankind.

Medicine until modern times was a species of dramatic play upon emotions rather than a science made useful through technology. It combined centuries of experience in trial and error in reactions from many drugs, with a maximum of skill on the part of the practitioner in a kindly art of making the patient feel as hopeful and comfortable as possible while he was dying of the disease, the origin and treatment of which were as yet undiscovered. Providence was made responsible for his fate rather than the bacillus which should never have been allowed to infect him.

Modern medical practice, however, is based upon a vast background of scientific research and discovery. In the creation of this science, in the conversion of its principles in technical methods for use in actual practice, in the diffusion of knowledge of these principles and methods and in the application of them upon a national and world-wide scale, Dr. Welch has played a leading part.

As a research worker in pure science he has made original and valuable discoveries. As a technologist he has devised practical methods of applying pure science. As a teacher he has spread true knowledge and inspiration among thousands and hundreds of thousands. But in organizing and directing research and application of medical knowledge on a wider field of prevention of disease, he is among the preeminent few who deserve the title of statesman.

No valuable change in every-day practice of any of the great arts has ever been made that was not preceded by the accretion of basic truths through ardent and painstaking research. This sequence that precedes effective action in medicine is equally important in every field of progress in the modern world. It is not the method of stirred public emotions, with its drama of headlines; it is rather the quiet, patient, powerful and sure method of nature herself of which Dr. Welch is the master.

Dr. Welch has happily combined in his character and intellect the love of truth and the patient experimental habit of the pure scientist with the ingenuity of the inventor and the organizing vision and energy of the promoter of sound enterprise—and combines all these things with a worldly wisdom and gracious charm that have made him a leader among men.

I know that I express the affection of our countrymen and the esteem of his profession in every country when I convey to him their wishes for many years of continued happiness.

[1] Address by President Hoover given in Memorial Continental Hall, Washington, on April 8, and transmitted by radio to institutions in many parts of the world.

STEPHEN ALFRED FORBES

THE DISTINGUISHED NATURALIST WHO DIED ON MARCH 13 AT THE AGE OF EIGHTY-SIX YEARS.

STEPHEN ALFRED FORBES[1]

My army service, concerning which you ask particulars, was begun by my enlistment as a private in Company B, 7th Illinois Cavalry, in September, 1861, when I was seventeen years old. At eighteen I was made orderly sergeant; at nineteen, second lieutenant, and at twenty, captain of my company. Just after my eighteenth birthday, when sent to carry an important dispatch to a distant outpost near Corinth, Mississippi, I was put upon the wrong road and presently found myself inside the rebel lines as a prisoner of war. Telling my captors that I had a verbal message only, which I refused, and they did not compel me, to disclose, I availed myself of an opportunity to tear up my dispatch, secreting the fragments in the pistol holster on my saddle. At General Bragg's headquarters I was threatened with hanging if I did not produce my dispatch and was thoroughly searched for it, as was also my saddle, but nothing was found. Later in the day I had a brief interview with General Beauregard, in command of the rebel army after the battle of Shiloh, and a much longer one with a major of his staff, who ended by wishing me good luck, and telling me to appeal to him if I got into trouble. I was in prison four months, at Mobile, Alabama, Macon, Georgia, and Richmond, Virginia. Utilized my abundant leisure by studying Greek from books which I managed to buy at Mobile. When paroled and released, I was sent to a hospital for three months to recover from scurvy and malaria, acquired in prison. Rejoined my regiment, reenlisted for the war, and was mustered out in November, 1865.

My formal education, concerning which also you ask, was incomplete and fragmentary, partly because of the poverty of my family, my father, a pioneer farmer, having died when I was ten years old, and partly because the Civil War took me away as I was getting ready to enter college. When I returned, I began and nearly finished a course in medicine at Rush College in Chicago, but becoming infatuated with a study of the botany of southern Illinois, I changed my plans, taught school for a living, and studied natural history as an avocation, with the result that when Major J. W. Powell, afterwards U. S. geologist, resigned in 1872 as curator of the museum of the State Natural History Society at Normal, Illinois, I was chosen to succeed him there. In 1877, when the present State Museum was established at Springfield, the Normal Museum, which had become the property of the state, was made the State Laboratory of Natural History, and I was appointed its director.

From 1875 to 1878 I was also professor of zoology in the State Normal University, and in 1882 was appointed state entomologist of Illinois by Governor Cullom. As the state had not furnished that officer with any office, equipment, collections, library, assistance or appropriation (except for his personal salary), the work was provided for by merging it with the State Laboratory of Natural History, and this was transferred by legislative enactment in 1884 to the University of Illinois, to whose faculty I had been appointed, as professor of zoology, in March of that year. It was also in 1884 that Indiana University gave me the degree of doctor of philosophy "on examination and thesis," entirely the product of private study, as I had taken no academic college course and had no bachelor's degree. In 1905, when I resigned as dean of the College of Science, the University of Illinois conferred on me, in recognition of my sixteen years' service in that capacity, the honorary degree of doctor of laws. In 1909 my professor-

[1] From an unpublished autobiographical sketch in a letter written by Professor Forbes in 1923.

ship was changed from zoology to entomology, and in 1921 I retired from the university service in order to give my undivided attention to the State Natural History Survey, of which I was appointed chief on its organization in 1917, under the Civil Administrative Code. I am, of course, a member of several learned societies, the most important of which are the National Academy of Sciences, the American Philosophical Society, the Entomological Society of America, the American Society of Economic Entomologists and the Société Entomologique de France.

I am aware that this bare outline of a scientific and educational career makes about as good reading as a dictionary or a table of statistics, but if you should ever want meat for its dry bones, I suppose that you will have to go to my friends and colleagues for that.

TWO-WAY TELEVISION

THE work of Dr. Herbert E. Ives and his associates in the Bell Telephone Laboratories during the past three years has culminated in a two-way television apparatus. The system which was demonstrated at their institution in April marks another important step in the development of electrical communication.

To carry on a conversation with a person at a distance, a person seats himself in a "television-telephone booth" before a frame in which he will see the face of the person with whom he is to

WALTER S. GIFFORD, PRESIDENT OF THE AMERICAN TELEPHONE AND TELEGRAPH COMPANY (SEATED), AND DR. H. E. IVES, OF THE BELL TELEPHONE LABORATORIES, IN THE TELEVISION BOOTH.

DR. F. B. JEWETT, PRESIDENT OF THE BELL TELEPHONE LABORATORIES (SEATED), WITH DR. FRANK GRAY, WHO HAS PLAYED A PROMINENT PART IN THE DEVELOPMENT OF THE TELEVISION APPARATUS.

talk. His own face is rapidly scanned by a mild beam of blue light which is reflected from his face to the photoelectric cells and gives rise to the current which transmits his image to the distant booth. There is no fierce glare to the scanning beam, and one is not annoyed by its presence and may even gaze directly at it without inconvenience. The first thing the observer notices when he steps into the booth, which is lighted with a dim orange light to which the photoelectric cells are insensitive, is the absence of the usual telephone. Special telephone transmitters and receivers are concealed in the booths. One talks face to face to the distant person, and a hidden receiver speaks the words which seem to issue from his mouth. An ordinary telephone is not used because it would hide part of the speaker's face from his distant observer.

The other party to the television-telephone conversation appears with sufficient detail for recognition of facial expression, but the effect is rather like looking at an animated cabinet-size photograph. This is because the image is produced in monochrome. What one sees is like an instantaneous moving picture done in black on a pink background caused by the color of the neon tube, whose flashing light viewed through the synchronized scanning disk forms the image. This image, which has the detail of about five thousand discrete points of light, is formed eighteen times a second. The photoelectric cells, used in picking up the face which is to be transmitted, have been much improved

H. M. STOLLER, OF THE BELL TELEPHONE LABORATORIES, WHO IS RESPONSIBLE TO A LARGE EXTENT FOR THE DEVELOPMENT OF THE SPECIAL MOTORS USED TO DRIVE THE SCANNING DISKS IN SYNCHRONISM.

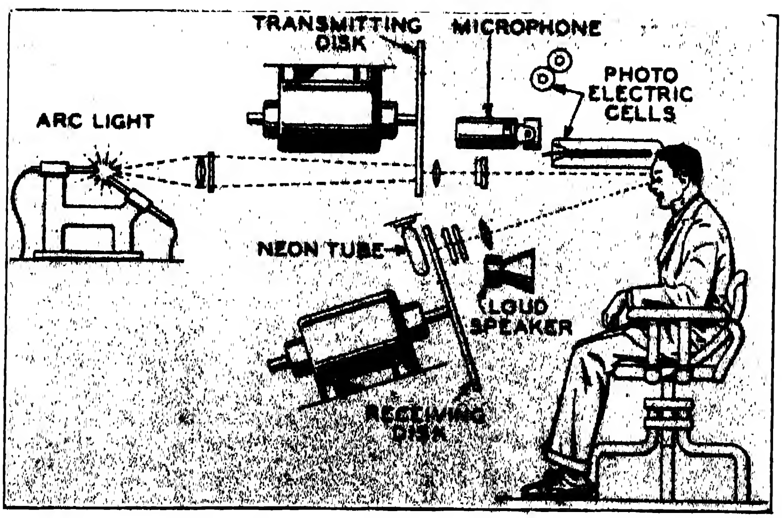
in sensitiveness and give rise to about ten times the current for the same amount of light as did those developed for the earlier demonstration. That increased sensitivity and the use of the blue scanning beam have made possible the reduction of the dazzle and glare which occurred to a certain extent in the earlier forms of apparatus. The person whose image is being transmitted is, therefore, practically unconscious of the fact that his face is being swept eighteen times a second by a scanning beam of light, and the beam is not bright enough to interfere with his seeing the image of the person to whom he is talking. The increased area and detail of the image necessitate the use of a wide band of frequencies, and the circuits between the two laboratory buildings have been adapted to the transmission of a frequency band of forty kilocycles.

According to a statement prepared by Dr. Jewett, the equipment now available for television is simpler and more efficient than that employed in the 1927 demonstrations and the results are very greatly improved, but the terminal apparatus is still inherently complicated and expensive. This complication arises out of the necessity for producing, transmitting and reproducing a large number of distinct images each second if good results are to be obtained. No practical suggestions for eliminating this fundamental requirement have as yet been made, and there appears to be nothing promising in our present knowledge of physical science. Correspondingly, the requirement that what is in effect a very

THE THREE MAJOR CABINETS OF THE TELEVISION-TELEPHONE APPARATUS

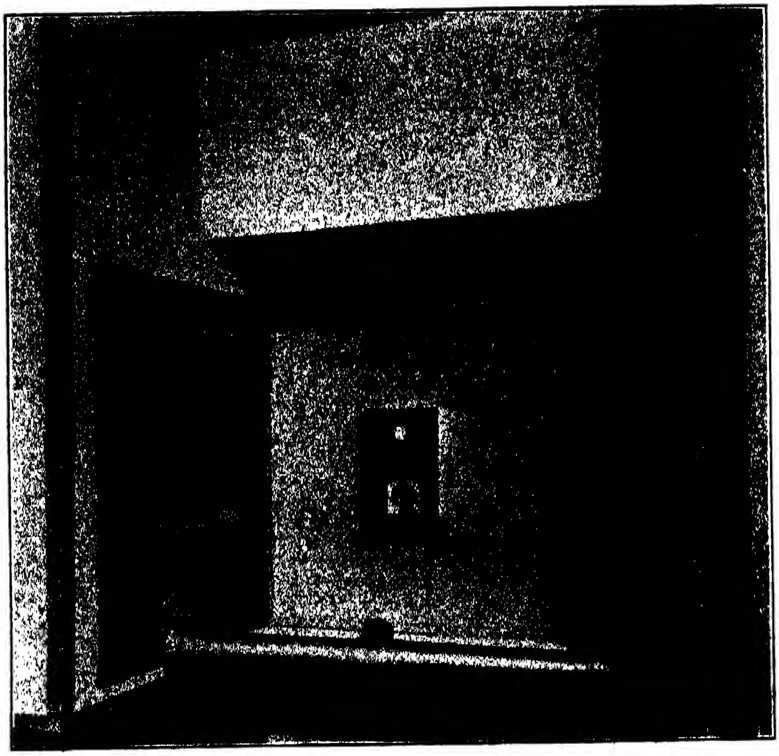
SHOWING THE TERMINALS OF THE PHOTOELECTRIC CELLS ON THE RIGHT, THE SCANNING DISKS FOR RECEIVING AND SENDING IN THE CENTER AND THE ARC LIGHT AT THE LEFT.

wide band of frequencies be transmitted leaves the transmission channel problem essentially unaltered. The requirement of an extremely wide transmission band and the further requirement that during the period of transmission the channel or channels must have a high degree of electrical stability and freedom from extraneous interference make the channel problem both difficult and expensive. Unlike telegraph or telephone transmission, where a limited amount of channel instability or a moderate amount of electrical interference can be present with-



A DIAGRAM OF THE APPARATUS

A BEAM OF LIGHT FROM AN ARC LIGHT IS THROWN BY A SCANNING DISK ON THE SPEAKER'S FACE, AND REFLECTED LIGHT IS PICKED UP BY PHOTOELECTRIC CELLS AND TRANSMITTED ELECTRICALLY TO THE DISTANT END. THE INCOMING IMAGE IS SEEN BY MEANS OF THE LOWER SCANNING DISK AND A NEON TUBE. A CONCEALED MICROPHONE AND LOUD-SPEAKER ACT AS SPEECH TERMINAL ELEMENTS TO COMPLETE THE TELEVISION-TELEPHONE SYSTEM.



THE INTERIOR OF THE BOOTH

In the lower part of the opening one sees an image of the person at the distant end. From a point just above it, the scanning beam is directed to the face of the speaker, and the reflected light is picked up by photoelectric cells visible through the glass plates at sides and top.

out serious impairment of service, telephotography and particularly television require practically perfect interference-free channels. For these services any marked instability in the channels or any substantial electrical interference registers at once as a serious defect in the received image. It is for this reason that while radio channels, if otherwise available, can be used for the transmission of television, they are not in the present state of the art as suitable as wire channels. Wire telephone circuits, particularly if in cable, can be maintained at a high degree of constant transmission efficiency and freedom from extraneous interference. Radio channels, on the other hand, are subject to the well-known vicissitudes of fading, static and interference, all of which result in a degraded received image.

Although, on account of its present complexity and high cost, no substantial commercial field is yet in sight for television requiring good images, there is still a large amount of technical work which gives promise of decided improvements over the means and methods now available. Both because of this fact and because of the collateral influence which research and development work in the television field has on general communication problems, Bell Telephone Laboratories will continue to explore the field of television.

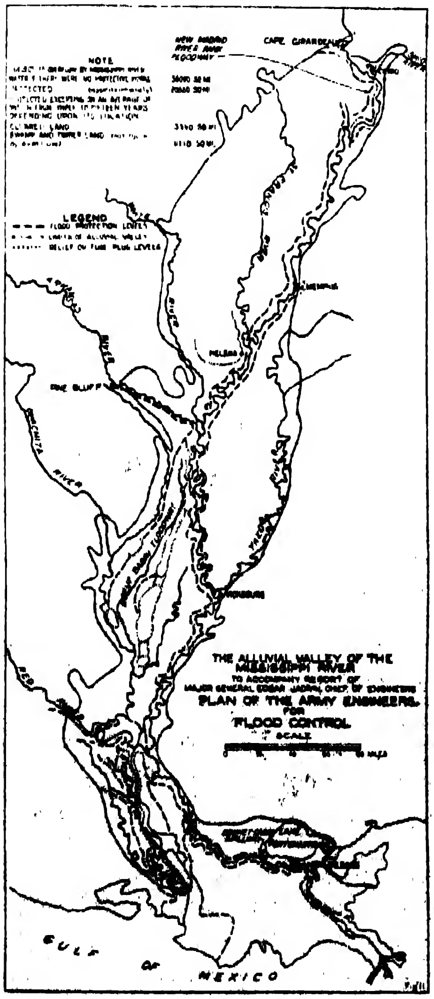
THE SCIENTIFIC MONTHLY

JUNE, 1930

FLOOD CONTROL WORK ON THE MISSISSIPPI

By Major General LYTLE BROWN

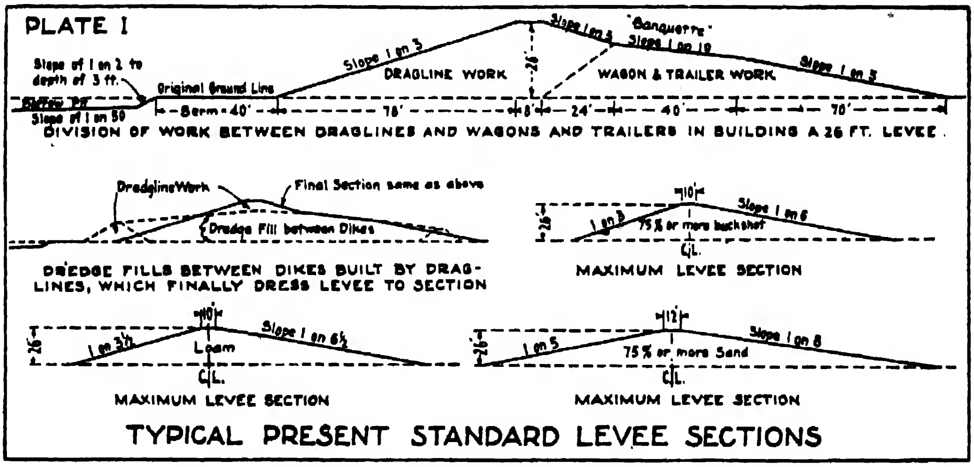
CHIEF OF ENGINEERS, U. S. ARMY



WHEN the term Mississippi Valley is used it generally means the lands bordering the Mississippi River which are naturally subject to overflow by the highwaters of the river. These particular lands consist of alluvial soil which has been deposited by overflows throughout the ages. The real highwaters of the river always occur in the spring between February and June. They vary in height from forty feet above low-water stage to sixty or seventy feet above low-water stage. Since the banks of the river are about forty feet above low water the waters generally rise during each spring high enough to overflow the lands. However, there are some seasons in which the waters rise barely enough to overflow the banks of the river. And of course the extreme highwaters are not very frequent.

For over a hundred years the people of the Mississippi Valley have been protecting their lands from overflows by means of levees or earthen dams. At this time the levees are from twenty to twenty-five feet high above the natural bank level so that all but the major highwaters are restrained between the levees and kept off the lands through which the river flows.

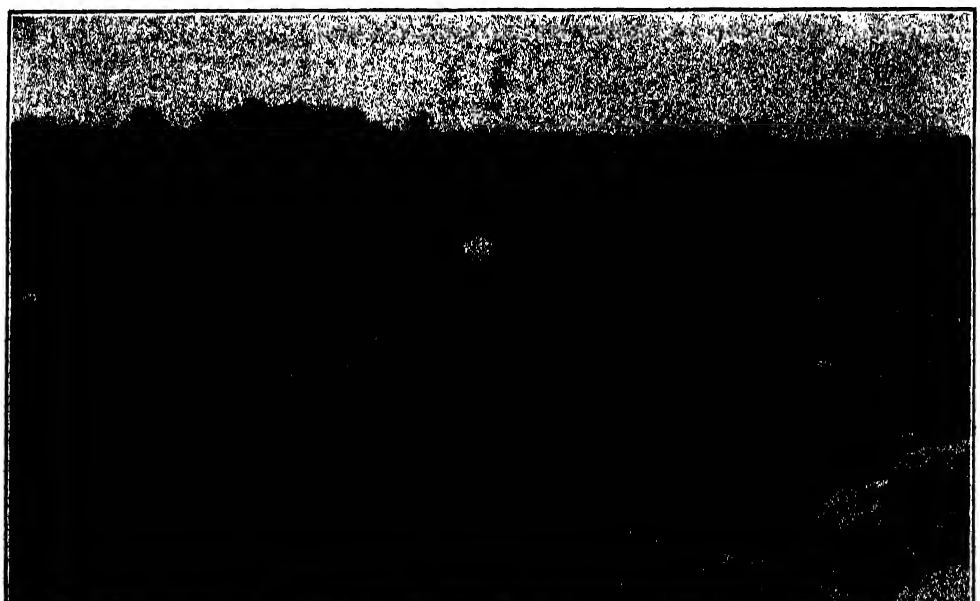
When levees were first used they were merely small mounds of earth thrown up around individual plantations. Gradually these mounds were made higher and



TYPICAL PRESENT STANDARD LEVEE SECTIONS

higher. Plantations began to combine their protection levees, and these grew into a system of levee districts which were chartered by the several states. These levee districts are political subdivisions that can raise taxes and expend funds. They do not always happen to fit in with the physical situations with respect to flood control. However, in such cases they have frequently united in the expenditure of funds for their mutual protection. Now the United States is bearing almost all the expense of flood control in the lower Mississippi Valley.

The alluvial valley of the lower Mississippi is composed of five major basins, which are the logical parts to consider



METHOD OF TREATING SAND BOILS
BETWEEN BATON ROUGE AND NEW ORLEANS, LOUISIANA, ON THE MISSISSIPPI RIVER.

from a flood protection point of view. In each of these basins is a major water course which can serve for local drainage. There must be outlets for local drainage, and each basin has such an outlet either into the Mississippi itself or into the Gulf of Mexico. These basins are the St. Francis Basin in Missouri and Arkansas, the Yazoo Basin in Mississippi, the Tensas Basin in Arkansas bales of superior cotton to the acre on some of these lands is sufficient explanation of the efforts made to reclaim and protect them. Naturally the production of wealth by fertile lands brings about the establishment of prosperous towns and even wealthy cities within the overflow territory. These serve as a major incentive toward protection against flood waters.

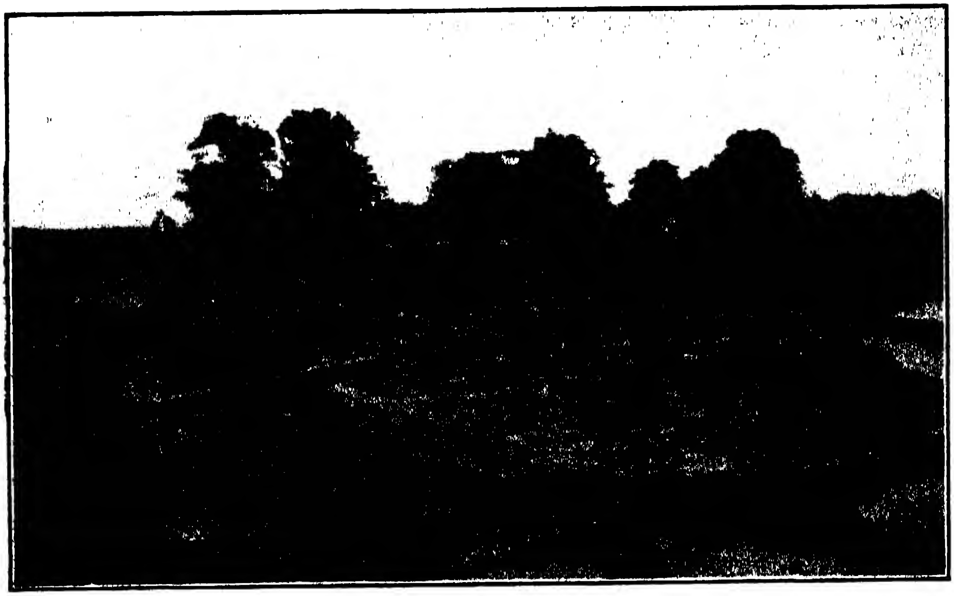
TREATMENT OF SAND BOILS

NEAR BORDELONVILLE, LOUISIANA, ON BAYOU DES GLAISES.

and Louisiana, the Atchafalaya Basin in Louisiana and the Pontchartrain Basin in Louisiana.

The alluvial lands in Missouri, Arkansas and Mississippi are used mostly for cotton. In Louisiana sugar as well as cotton is grown. It is worthy of note that the fertile soil of the alluvial valley produces a long staple cotton which is superior to the cotton grown on hill lands and brings a higher price. The yield of these lands is also greater per acre than that of hill lands. The fact that it is possible to raise as much as two

Nature has brought about the alluvial valley by successive deposits from overflows. When overflows were not prevented, each year saw an addition to the land elevation. The spilling of water out of the river channel caused greater deposits close to the river channel than at a distance from the river because where the current was first checked the deposit was greater. In this way the river banks grew higher than the general elevation of the valley. When levees were located they were naturally placed on the highest ground, and this in gen-



RINGS OF SAND BAGS

AROUND SAND BOILS NEAR NEW ROADS, LOUISIANA, DURING FLOOD FIGHT.

DUMP WAGON

OF SEVEN-YARD CAPACITY, USED IN BUILDING LEVEE

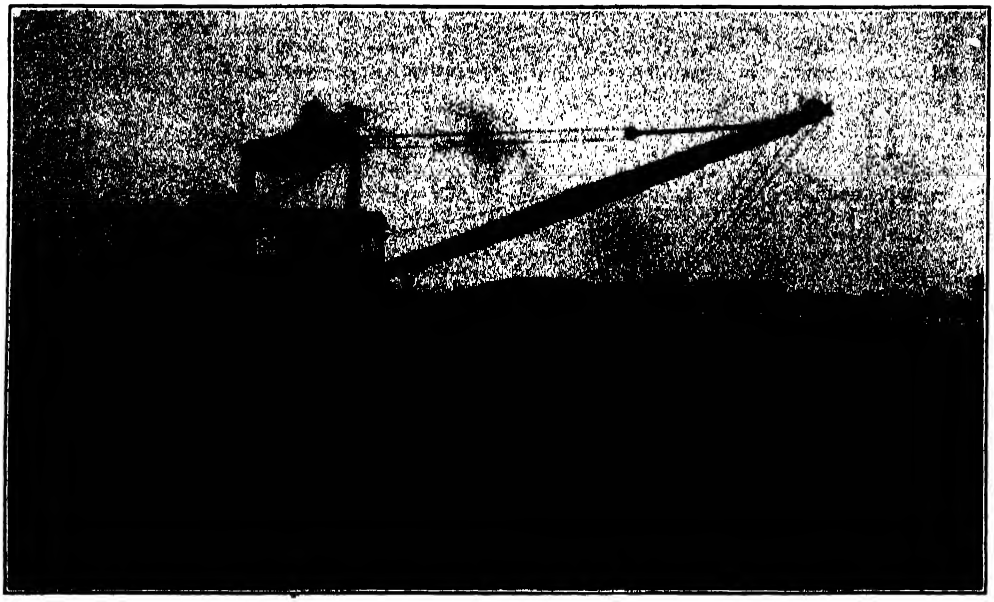
eral is near to the channel. This has an advantage since all the local drainage flows away from the levee toward interior tributaries which ultimately empty into the main river or into the gulf.

The deposit from overflow water is fine silt and is very fertile. After each overflow the land usually produces much better crops than it has produced when not subjected to overflow and silt deposit. The Mississippi Valley is so fertile that in general it has not suffered from lack of productive capacity. This is the case partly because no portion of it has up to this time been entirely protected from overflows for long periods of time. However, in recent years some of the lands have begun to show deterioration because they have been protected for a long time. For example, in the upper Yazoo Basin protection has not failed for forty or fifty years and the land is becoming reduced in fertility. Now that the greater part of the valley is to be given total protection this question of the wearing out of agricultural lands may become a problem.

The backbone of flood protection is a system of levees or dikes or earthen dams, which hold the waters of the Mississippi River within or approximately within its channel. These dams can be constructed only of the soil where they are located because any other type of construction would cost far more than the values protected. The construction of levees with this soil is fraught with many difficulties on account of the nature of the earth and the foundations

"B" TYPE CATERPILLAR LEVEE MACHINE

PROPERTY OF INNES CONTRACTING COMPANY. LEVEE WORK AT RICHARDSON POINT, RED RIVER, ARKANSAS. THREE-YARD SCRAPER, 85-FOOT BOOM. A CONVERTED "BUCYRUS" STEAM-DRIVEN MACHINE, NOW AN OIL-BURNING DIESEL ELECTRIC OUTFIT. FEBRUARY 11, 1929.



AUXILIARY DRAG LINE LEVEE-BUILDING MACHINE NO. B-8

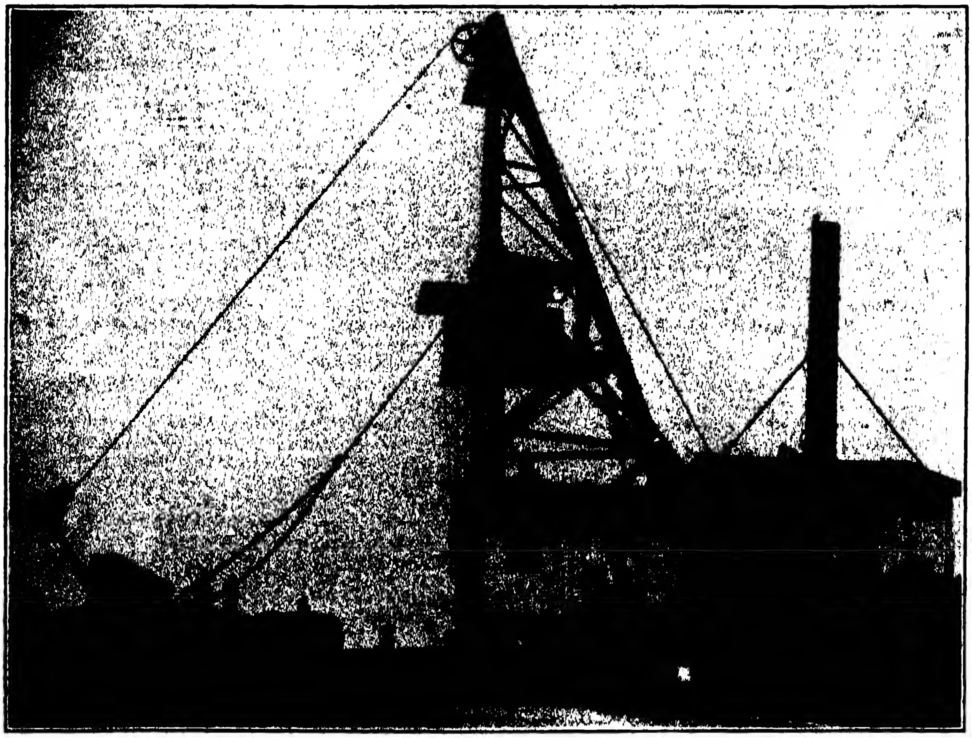
SHOWING LEVEE WITHOUT BANQUETTE BEING LEVELED TO BANQUETTE GRADE IN ADVANCE OF ENLARGEMENT. OCTOBER 19, 1921.

MACHINE C-6 IN OPERATION

HAYTI, MISSOURI. NOVEMBER 22, 1928.

encountered, but these difficulties must be overcome with the materials at hand since, as stated above, the use of any artificial material is too expensive to be permissible.

The earth which serves as foundations for the levee is the same alluvial material that forms the body of the levee. It is true that this varies somewhat, but none of it is any too good. It may be black clay, called locally buckshot, or sand or fine silt. Usually it is a mixture of sand and silt. It is more or less porous and will not bear excessive weight. Sometimes levees when built to the height desired—from twenty to thirty feet—will sink on the foundations. This may be accompanied by the rising of earth near by or there may be no indication at all where the levee material goes. In such cases apparently the foundation acts like a tube of toothpaste and material is squeezed out at some distant point which is never discovered. When subsidence is accompanied by a raising of nearby material the defect can sometimes be remedied by loading with earth the place that rises. Usually about all that can be done is to keep putting material on the levee until equilibrium is established sufficiently to permit the levee to be raised to the grade desired.

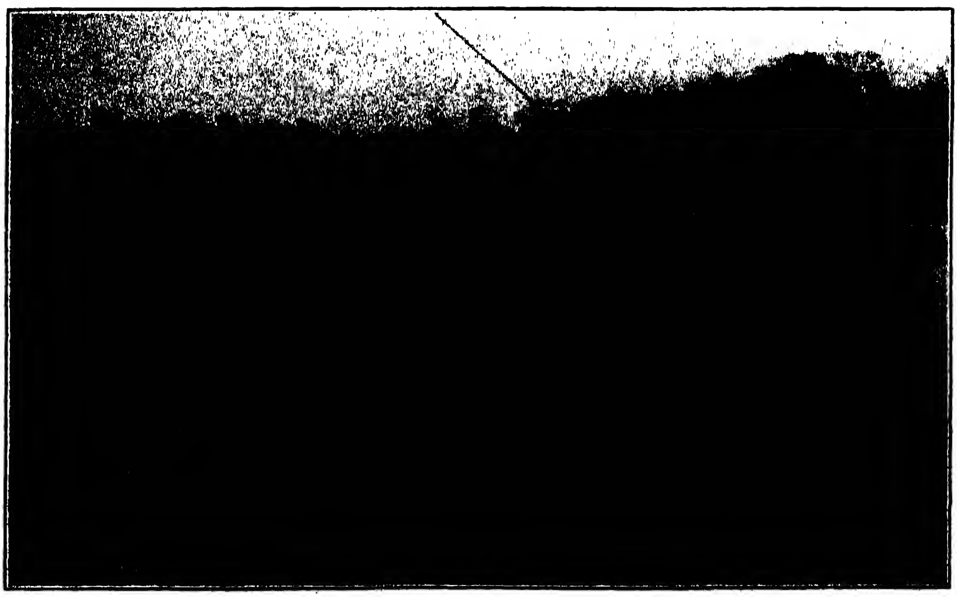


TOWER EXCAVATING LEVEE–BUILDING MACHINE C–7

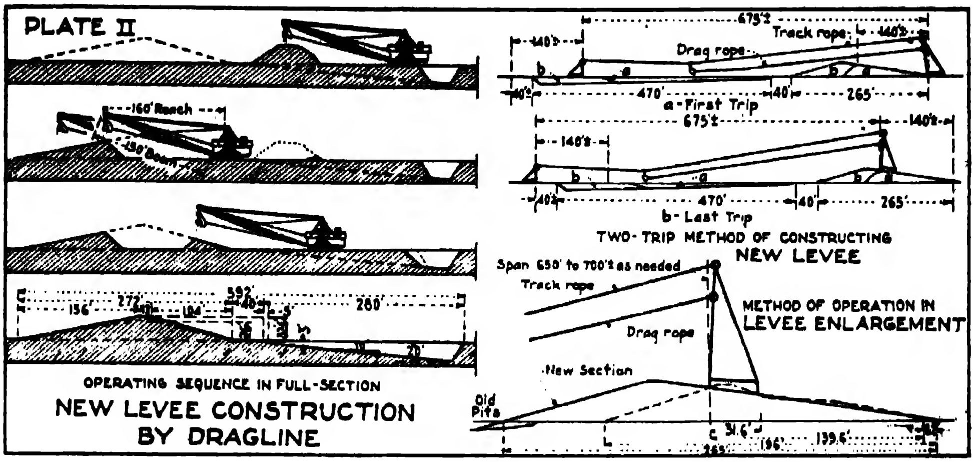
SHOWING MACHINE ON BANQUETTE ENLARGING LEVEE.

The porous fundations permit water to percolate under the levee and come up on the land side. This is very dangerous if the water moves fast enough to transport material with it because such a process will soon create a cavity under the levee. A cavity underneath will of course cause the levee to drop and turn

C-6 BUILDING BANQUETTE
WHITE HALL, ARKANSAS, 1924.



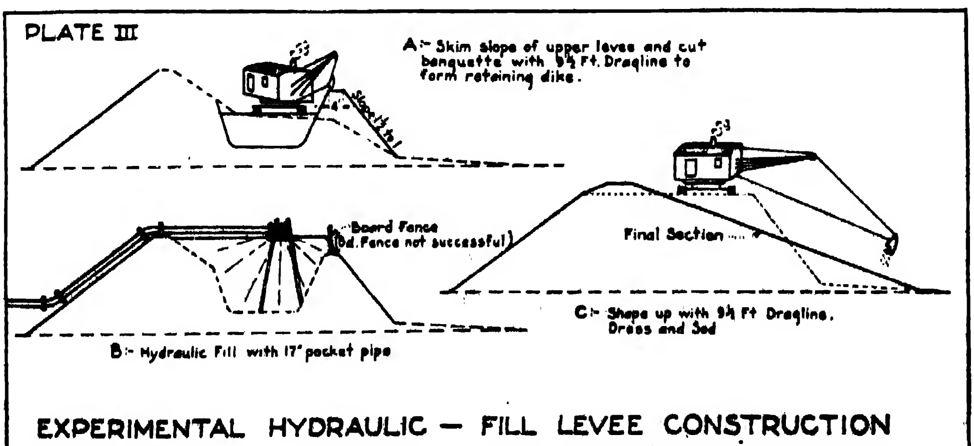
MACHINE C-6 IN OPERATION
HAYTI, MISSOURI. NOVEMBER 22, 1928.



the flood waters loose over the land. The rate of this underground percolation is kept down by making its path long enough to preclude fast enough movement to transport material. This is produced by making the base of the levee wide enough. And the base always has a "muck ditch" in it to cut off lines of seepage and lengthen the paths of percolation.

When water moves under a levee too fast it is indicated by a "sand boil" behind the levee. This is a bubbling up of water carrying sand. When a sand boil starts it must be stopped promptly. The method used is to build with sand-bags a circular well around the sand boil. The water rises in this well and creates a hydraulic head against the percolating water so that its velocity is slowed down to the point where it can not carry material from underneath the levee. When there is a major highwater in the river and the water has risen to near the top of the levees, at places where foundations are not good, back of the levees, the adjacent territory will be sprinkled with these sand-bag wells to nullify the danger from sand boils. At such times all levees are patrolled and watched night and day for evidences of weakness.

Seepage through the levee itself occurs



U. S. DREDGE *OMEGA*

BUILDING NEW LEVEE AT MOUND LANDING CREVASSE. SEPTEMBER 29, 1927.

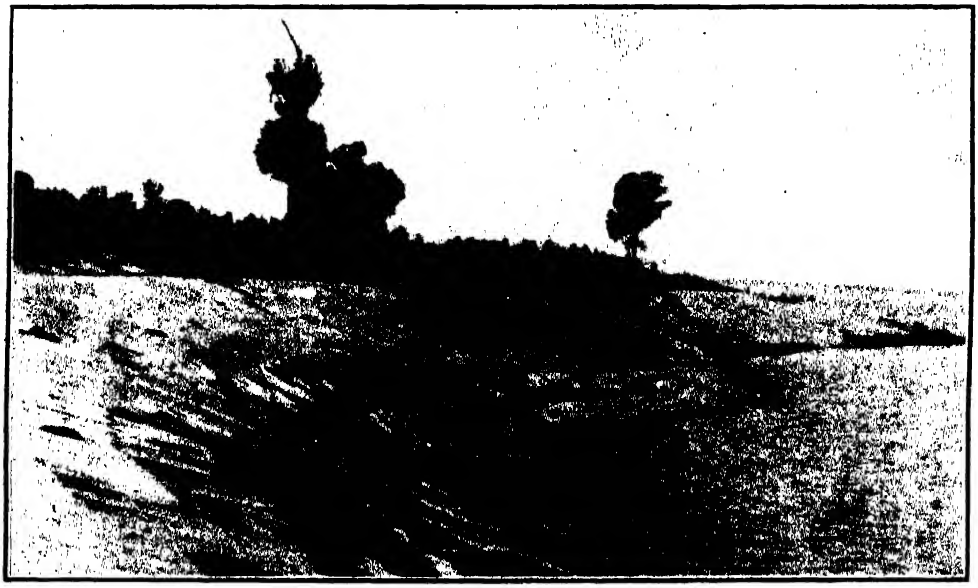
CONCRETE REVETMENT, HUFFMAN, ARKANSAS

OCTOBER, 1927. SLABS PLACED ON BANK WITH DERRICK BOAT.

when water rises high against it. This like a sand boil must be kept down to safe velocities. This is accomplished by having the levee thick enough and broad enough at the base to inclose the line of saturation.

A wet levee will sometimes slough or slide; that is, the earth becomes so saturated that great portions of it slide off. The sections used are designed to be large enough to prevent this, but at times wet places that might slide have holes in a levee and make it unsafe. However, abundant material in the design is the best that can be done, and this is limited by cost. Sodding and careful maintenance by preventing weeds and trees from growing on the levee help to avoid failures. Cattle must be kept off a soft levee so that their hoofs will not destroy the sod which aids in keeping the levee firm.

The levees now being constructed in the Mississippi Valley are from twenty

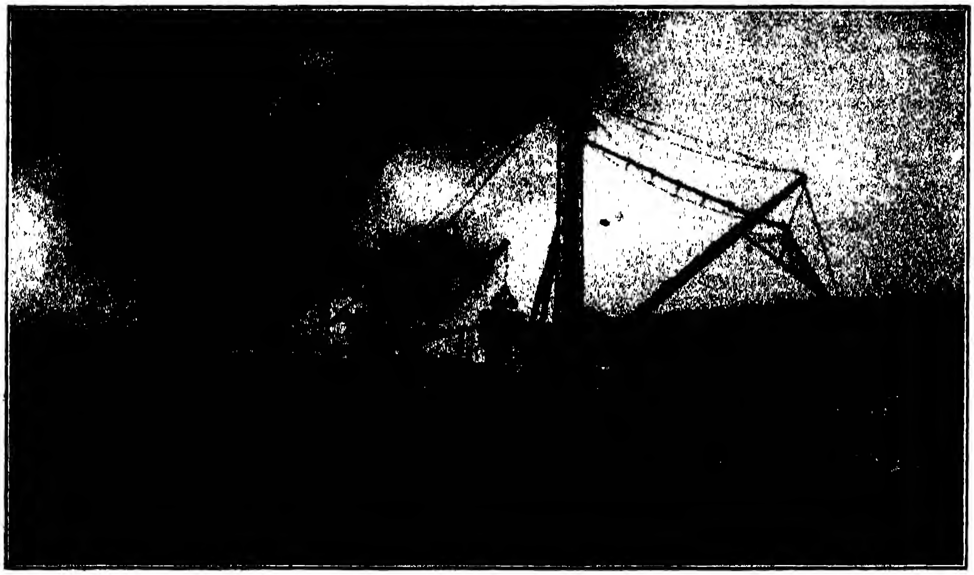


CONCRETE REVETMENT OF PREPARED SLOPES

BY PAVING WITH CONCRETE PLACED *in situ*. GILES BEND, LOUISIANA; CONCRETE PLACED IN 1924. OCTOBER 3, 1929.

to be plastered with sand-bags placed as an emergency measure. If the sliding is too bad it may be necessary to construct an emergency loop around the bad place. This must necessarily be an improvised substitute levee made with sand-bags or earth held up with lumber.

The surest way to prevent accidents is to have the levee high enough and broad enough to preclude dangerous percolation, seepage or sloughing. But muskrats and other small animals may bore to thirty feet high. They are ten feet wide on top and from two hundred to three hundred feet wide at the base. These levees are quite stable and safe. Their construction is an enormous job. Millions of yards of earth must be scraped up and placed to form these dikes. The river below Cairo, Illinois, is about a thousand miles long and for the greater part of this length there are levees on both sides of the river. It is true that the old levees are there and



FLOATING CONCRETE MIXER AND TOWER BARGE NO. 1712

SHOWING PLANT PLACING CONCRETE PAVING *in situ*. WILL PLACE CONCRETE 100 FEET FROM WATER'S EDGE AND 40 FEET ABOVE WATER. OCTOBER 19, 1921.

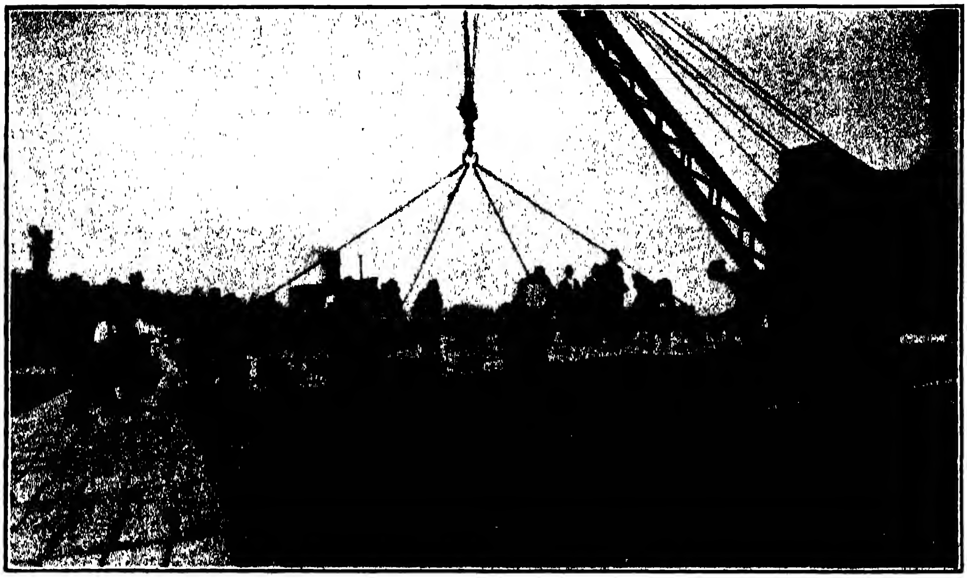
that most of the length requires only the raising and enlargement of the old levees. However, these are being made almost twice as large as they have been. In addition, in many places entirely new levees are being constructed.

When levees were first built the work was done by hand labor with picks and shovels and wheelbarrows. As they grew larger mule teams and scrapers were used. This levee construction was required to be carried up in layers two or three feet thick. Mules walking over the materials placed packed each layer and this resulted in the best kind of levee. Later mule and scraper work was supplanted by machinery because the amounts of earth to be moved were too great to be handled except by machinery within the time required and at the cost permitted. Machine work probably does not produce a levee equal in quality to the old levees but the increased size of modern levees more than compensates for any possible loss in quality.

Now that such enormous quantities of earth must be moved to carry out the adopted flood control project intense study is being given to earth-moving machinery with a view to the development of the best type for building levees. The necessity of moving the contents of a levee over a considerable distance must be kept in mind. Specifications prohibit digging and leaving unfilled borrow pits too close to the levees because of possible seepage, percolation and foundation troubles. The greater part of the levee work is done by contract, and there is keen competition among contractors. All the engineering ingenuity of these contracting firms is at work devising new types of machinery and new methods of operating types in existence.

Levee building machines include the following general types: drag line, floating clam shells, tower machines and hydraulic dredges.

In addition, levees are built with wagons and scrapers, with tractors and trailers and with industrial railroad tracks and derricks.



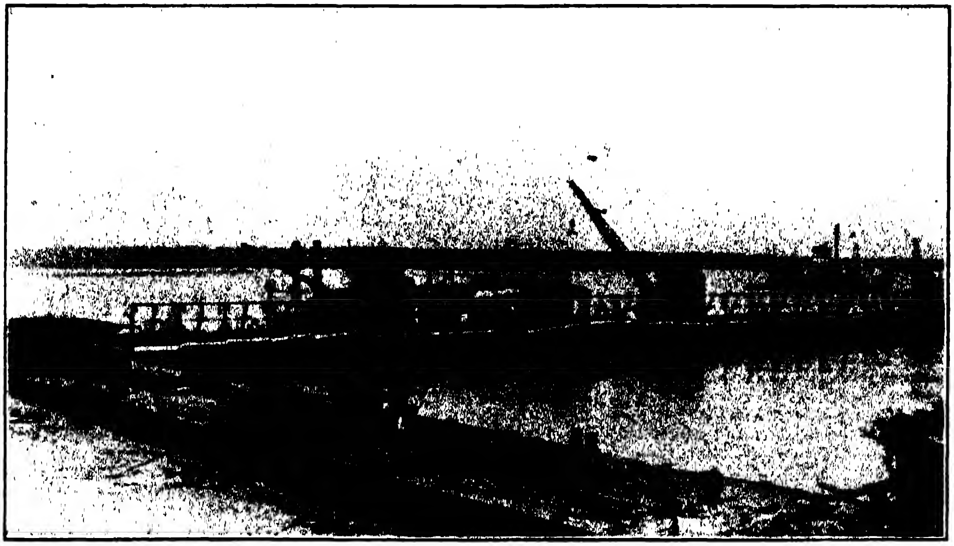
CONCRETE MAT-SINKING PLANT
IN OPERATION AT CAULK NECK, ARKANSAS. OCTOBER 13, 1927.

The drag line machine consists of a derrick on caterpillar or other treads having a long boom of moderate lifting power. A bucket or scraper swinging from the end of the boom scrapes up the earth by direct pull from the derrick engine. Then the boom has to lift only the material, swing it over the levee and drop it into place. Some double handling may be necessary.

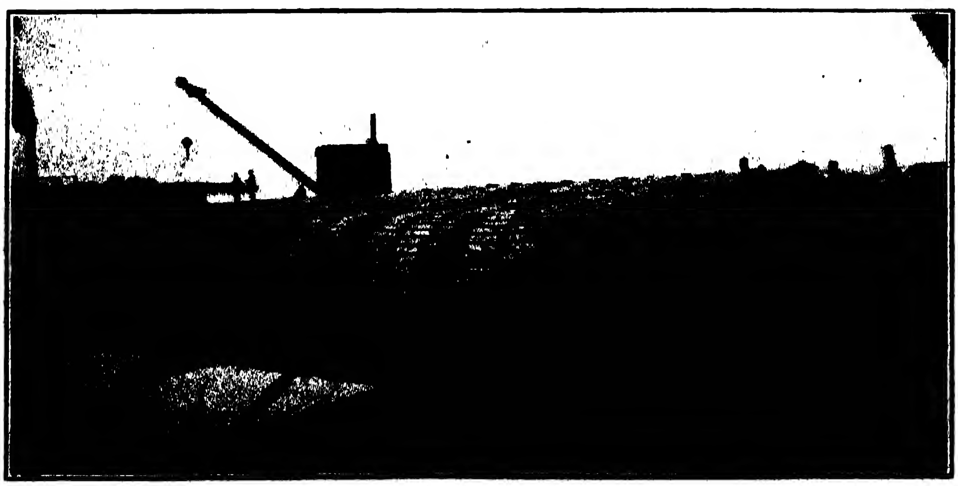
Floating clam shells have a very long boom, dig the earth with a clam shell bucket, swing it over the levee and dump it in place. These require a ditch with water in it from ten to twelve feet deep. Since the specifications do not permit such a ditch too close to the toe of the levee, these machines must have a very long boom. Even with the longest boom that has yet been devised, some of the material must be handled twice and this increases the cost.

Tower machines consist of a main tower back of the levee and a smaller support out in front of the toe of the levee. Both these towers are on wheels or skids of some kind. A line stretches between them and from it swings a bucket scraper device. The engine at the base of the higher tower pulls lines which carry the drag bucket empty to the smaller tower. It is then dragged toward the levee, filling from the borrow pit and dumping into the levee section. These machines were designed to fit the requirements of levee building, which include a wide borrow pit, shallow toward the toe of the levee and growing deeper as the distance from the levee increases. This machine is essentially a dry earth machine and builds levees of dry material which settle and are dry within the time required.

Hydraulic dredges can be used to build levees, but conditions have to be suitable if the construction is to be cheaper than can be accomplished by dry method machines. In addition the earthen dike must be carried up in layers in such a way as to permit drying out and proper settlement and compacting. Earth can be moved more cheaply by hydraulic method than by any dry method, but flowing wet material will



CONCRETE REVETMENT, HUFFMAN, ARKANSAS
OCTOBER, 1927. HEADER BLOCKS READY TO SINK.

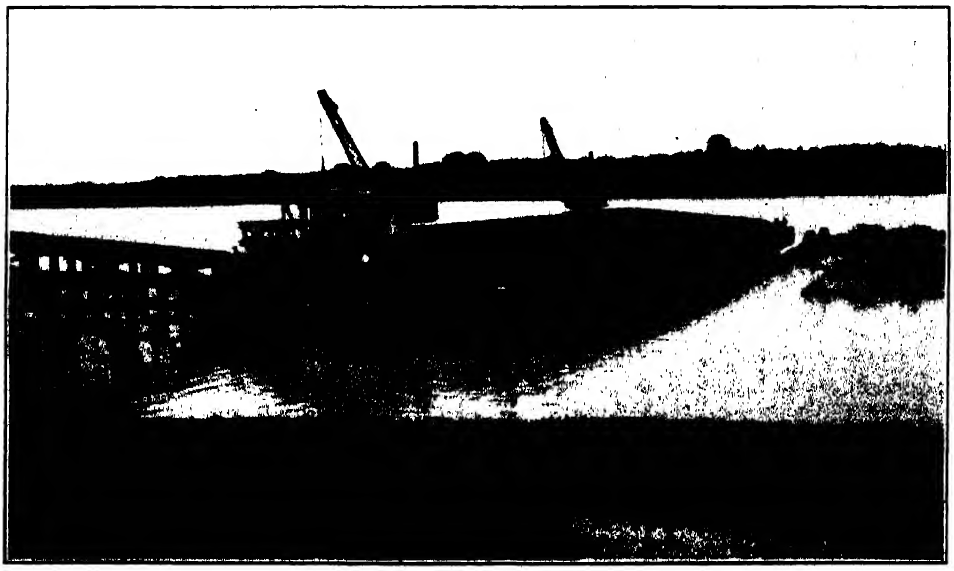


CONCRETE MAT-SINKING BARGE, NO. 1914
SHOWING REINFORCED CONCRETE MATS LAID READY FOR LAUNCHING. EACH LAUNCH 25 BY 140 FEET. OCTOBER 18, 1921.

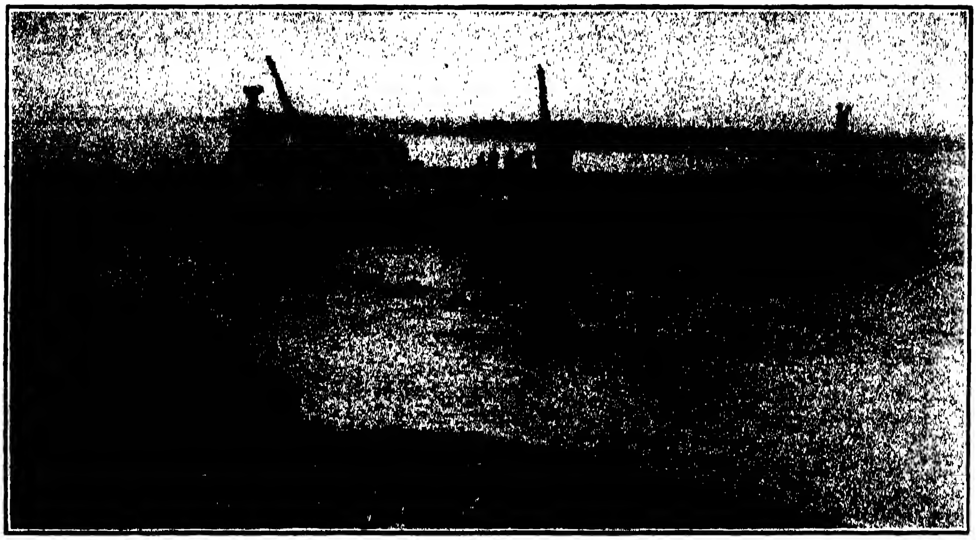
not settle in a levee section just in the shape desired. This results in material flowing out of the section paid for, so that the actual yardage paid for may cost more than an equal amount of yardage placed by a dry method.

The Mississippi River perpetually flowing through its valley makes its own channel. It scours at places and deposits at other places, depending upon the velocity of the water and the way in which the current impinges upon the banks. In concave bends the banks are continually crumbling away, while on convex banks depositing processes are going on. Thus the river gradually changes its shape and location wandering through the ages from one side of the alluvial valley to the other side. There is no such thing as a permanent fixed location of the river for all time. This moving process and caving away of banks periodically destroys levees located alongside up and down the river. Levees like buildings in cities must be considered of limited life. A levee is generally located sufficiently far from the river bank to give it not less than a thirty-year life. Usually it is more economical to move a levee than to prolong its life by stabilizing the bank of the river and thus retarding the natural processes of nature. However, at places it is expedient to stabilize the river bank and this is accomplished by means of revetments and bank paving.

Revetment is made in two ways, *viz.*, with willow mats and with flexible concrete mats. The mat is placed below low water, lying on the side and bed of the river to prevent scour and undermining. Above the mat the bank is paved with concrete or stone to prevent the washing away of the bank above the low-water line. Mats stay in good condition something like eighty years; there is considerable durability in them. However, they are much more expensive per linear foot of river than levees, and it is for this reason that levees are usually moved back in preference to revetting the river bank.



CONCRETE MAT–SINKING PLANT
SHOWING HULL AND SUPERSTRUCTURE.



NEW ORLEANS RIVER DISTRICT
LAYING OF CONCRETE MATTRESSES FROM BARGES.

A willow mat is made of young willow trees having a diameter of from one to three inches. These are bound together into a fascine or bundle from ten to sixteen inches in diameter. The fascines are tied together side by side with wire cable and poles until a mat is formed some 1,000 feet long and 300 feet wide. This construction is accomplished by a plant specially designed for the purpose. The mat is woven continuously on barges placed perpendicular to the bank of the river. As the weaving progresses the mat is slid into the water where it floats alongside the bank. After a mat is completed it lies floating alongside the bank for 1,000 feet of bank length. Then barges loaded with stone are placed alongside the mat. The stone is thrown on top of the mat and as the mattress sinks the stone barges float over it. Thus it is loaded with stone until it rests on the bottom. Being flexible it sinks into place in the shape of the bed and underwater bank of the river below low-water line.

After a mattress is in place the bank above is graded either by hand or by hydraulic jet until it slopes back from the water line with a stable slope. On this graded bank either concrete paving or stone paving on a gravel base is laid up to the top of the natural bank of the river. The levee line may be located either immediately on the high bank of the river or from five to ten miles back from the actual bank.

When the supply of young willows available for mattress work began to become scarce, a flexible concrete mat was devised which costs about the same as a willow mat and serves the same purpose. There are two types of concrete mattresses in use. One is composed of reinforced concrete slabs one foot by four feet in size tied together with wire with butt joints. The other type consists of larger concrete slabs five feet by eleven feet, overlapping each other in shingle fashion and also tied together with wire. These concrete mattresses are formed on barges where the wiring together of slabs is done. From the barge the mat is slid off into the water and sinks of its own weight. A concrete mattress is laid from

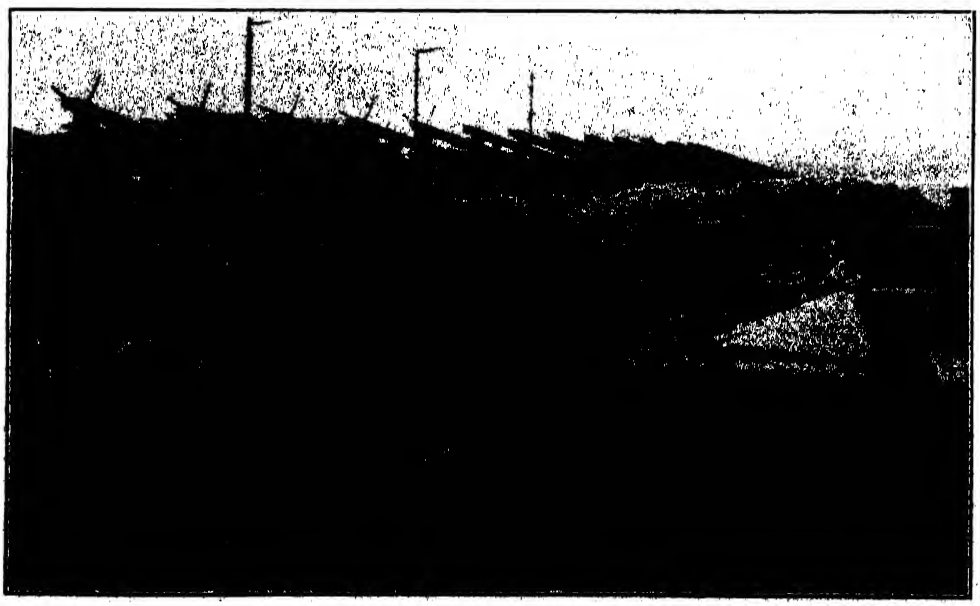
the bank line perpendicular out into the river. Like the willow mattresses these concrete mats are flexible and assume the shape of the under-water bank and the bed of the river.

The greatest bank caving is caused by the bank under the low-water line scouring out. The weight of earth above causes the higher bank to drop into the river. If the mattresses protect the under-water bank and extend well out into deep water this scouring under effect is eliminated. Of course there is also bank wash above low-water line but this is relatively small compared to huge masses of bank dropping into the river from under-water scour.

Revetment such as is described is used at critical points on the river to protect levee lines where it is inexpedient to move back these lines. At places towns and cities are located on the river banks and at these places the moving back of levees is impracticable. Greenville, Mississippi, is on the bank of the river and its levee must be and is protected by several miles of bank revetment. In a location of this kind it is essential to keep the bank revetment well maintained to prevent a disaster due to caving banks.

The City of Memphis is on high ground, not the alluvial valley proper, but the river currents impinge upon the edge of this large city and attack its foundations. Huge masses of earth have subsided toward the river at Memphis, taking down with them structures and improvements. These subsidences are being opposed by bank revetments of mattresses laid along the river bank as described.

New Orleans harbor is revetted. This large city is protected by a wide levee twenty-five feet above low-water stage. The city itself is all about twenty feet below the highest stages of the Mississippi River. The revetment in the harbor is extensive and has to be kept in good repair to prevent the banks from caving into the river. The levee line is immediately on the bank of the river, and high buildings, docks



MATTRESS PARTIALLY CONSTRUCTED

TO BE USED FOR BANK REVETMENT.

MOORING BARGES

AT PRINCETON, MISSISSIPPI. OCTOBER 18, 1921.

and other improvements are located on the very banks of the river. After the flood of 1927 there was unusual scour in the harbor followed by serious settlement of expensive docks. New repair mats were placed to stop this.

In addition to the levees and revetments for flood control purposes, a spillway is being constructed above New Orleans to let out from the main river sufficient water to reduce the amount that can possibly pass that city down to a quantity that can pass with absolute safety. This spillway is located at Bonnet Carre, about twenty miles above New Orleans. It consists of a masonry sill and movable dam 7,700 feet long and a floodway within which the discharged water can flow in safety to Lake Pontchartrain where it will be harmless. The dam can be removed when stages become excessive. Thus enough water will be permitted to escape to reduce the water in the main channel to the amount considered safe. The floodway stream will be over a mile wide and from ten to fifteen feet deep, flowing at velocities of from two to three and one half feet per second. This is of course a large river in itself. The main river at this point is wide and from sixty to one hundred feet deep. It flows at velocities of from five to seven feet per second. The main river is about five times as large in capacity as the spillway.

The adopted flood control project for the alluvial valley of the Mississippi provides for the expenditure by the United States of $325,000,000. This expenditure is to be made over a period of ten years. It is contemplated that after completion the adopted project will protect the greater part of the valley against the maximum flood predicted as possible. While the greater part of the area is to be thus protected, more especially are the parts that include the greater values to be protected. The centers of population and commerce are more important than areas alone.

After the pending annual appropriation ($35,000,000) has been expended there will have been spent about $100,000,000 toward the contemplated protection. At that time protection against any flood reasonably probable will have been completed. Already great additional protection has been afforded by the work of the government. During the spring of 1929 one of the highest waters ever recorded passed safely down the river into the gulf without a crevasse on the main river. The fact that there was no disaster caused this flood to pass unnoticed by the general public. It was the greatest flood that ever passed through the valley without crevasses and serious damages.

No one who has not traveled all along the levee lines between Memphis and New Orleans can realize the immense public work that they represent. Before the federal government set its hand to the work of flood control two years ago. the levee system already constructed stood as material evidence of the great energy, enterprise and determination of the people who live along the banks of the mighty stream. The whole world seems to know of the dikes of Holland, and of the tenacious courage and indomitable industry of the Dutch people. Some day when the proper literary genius comes along the story of the levees along the Mississippi will find its way into the vision of the world to the everlasting credit of the people of the great lower valley.

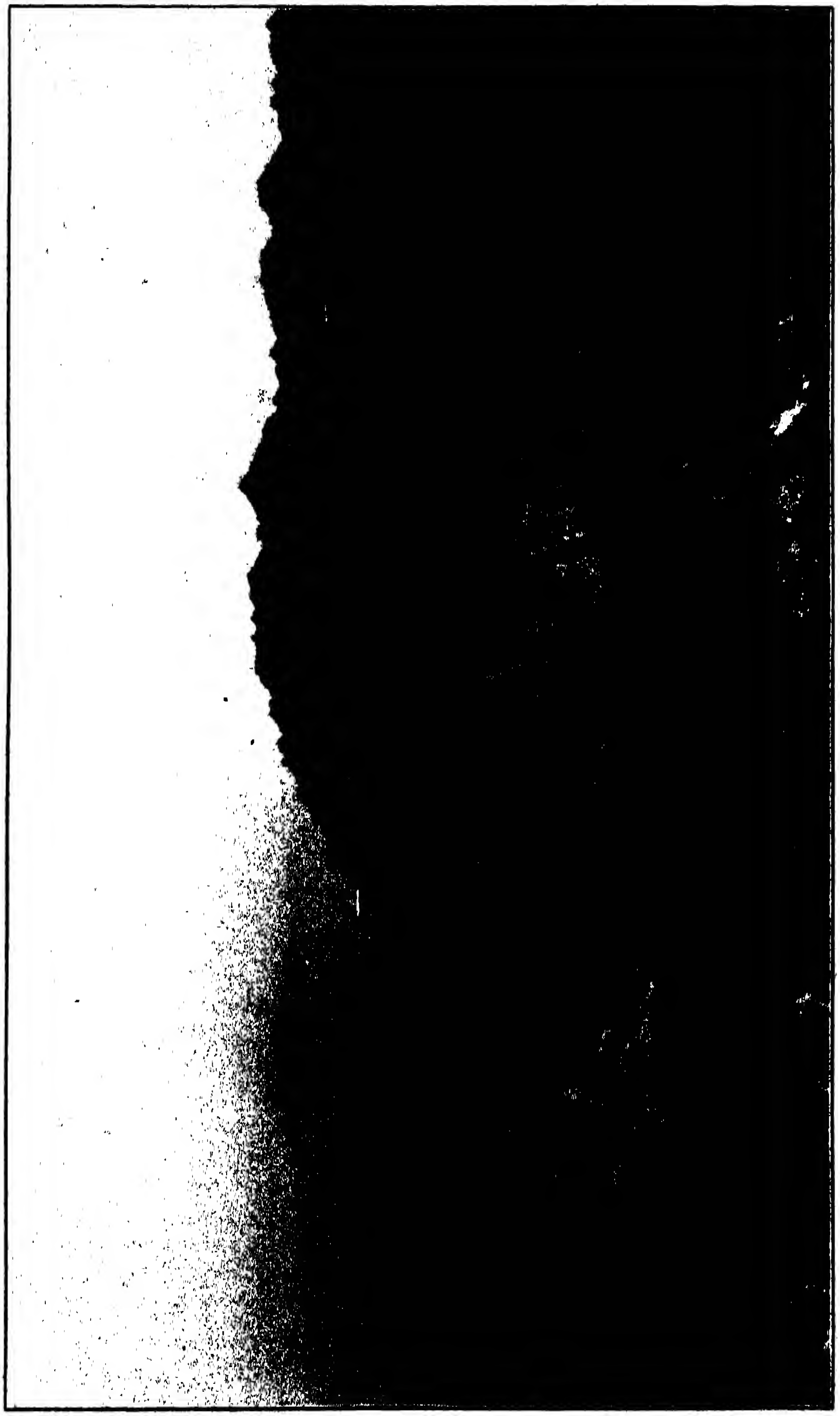
It is well for all to know that the federal government has never set its hand to the control of floods in the valley of the Mississippi as much as it did less than two years ago. While it did in the past concern itself to some extent with floods, it devoted itself primarily to the question of navigation. It gave assistance to levee building, but the bulk of that work has been done by the local people. The federal government's activities in levee building were first induced by the belief that to confine the flood waters to the channel would increase its depth and so improve its low-water condition as regards navigation. In the long run that belief may be correct, though men may have to wait over a long period before the results become very apparent.

It is the belief of many of the best informed that the levees along the main stem of the river have reached the ultimate height to which they should be raised. The failure of a high levee invites greater disaster than that of a low one. The denser population behind a levee and the greater improvement of the land, both of which are to increase with the prosperity and greatness of our country, cause the future to frown heavily on high levees. The limit of height seems to have been obtained from an economical view-point also, for the greater the height the greater the unit cost. The limit of height also is indicated in many places now by the tendency toward excessive settlement of foundations. Every consideration points toward keeping the levees as low as possible.

As means of keeping the levees low we have three courses of action: diverting water from the main channel, keeping it back from the main channel by storage reservoirs on the tributaries and straightening the main channel. These means are all very expensive and must be carefully considered before final decision as to the extent that any or all will be used, and how they will be used. We are in position to decide the diversion question were it not involved with the reservoir question to which we wish to give further consideration. The straightening of the channel must wait; we can not do it now.

Our hope is to solve this problem satisfactorily. There are three phases of it that require careful consideration as well as physical research. They are: (1) Economical bank protection to stabilize the levee system and improve the channel conditions for navigation, (2) storage reservoirs and (3) increased channel capacity by the elimination of bends.

Of these three phases of the question, (1) and (3) are interdependent, (3) not being practicable unless (1) is solved. I regard the development of an economical method of bank protection as the real problem of the Mississippi both as regards navigation and flood protection.



Photograph by E. D. Wilson, Arizona Bureau of Mines

SHARPLY ERODED VALLEYS IN ISOLATED MOUNTAINS OVER VALLEYLESS AGGRADED PLAINS

SOUTHWESTERNMOST ARIZONA.

PHYSIOGRAPHIC CONTRASTS, EAST AND WEST

By Professor Emeritus W. M. DAVIS

HARVARD UNIVERSITY

II

Washes and Wadies

The dry channel beds of valleyless intermont troughs and basins, commonly called "washes" in the West, are the equivalent of the "wadies"' of the Sahara.[19] They are as little known in the East as detrital fans. The larger washes lead down detrital-fan radii from valley mouths in the mountain margins, but myriads of little branch washes have their heads on the gentle declivity of the detrital slopes. The last flood that swept down a wash left the bed covered with gravels and sands as the flood water slowly drained away. The next flood will take up the gravels and sands as it rises, carry them farther forward toward the trough-floor plain as it runs and replace them with new gravels and sands brought from farther up the slope as it falls. In the long dry spells between floods, the convectional whirlwinds of hot noons lift the finer detritus from such washes as they happen to cross, carry it a short distance in the air and let it fall, hit or miss, on the plain. The persistent presence of drainage slopes and especially of the myriad little branch washes proves, however, that running water is the dominant agency of transportation, even though intermittent in its action.

Where the "wash" of an intermont plain has a cobbly or gravelly bed, its braided channel is broad and shallow; where it is cut in silt it is usually narrower and deeper. A silt channel may, indeed, be so deep as to be mistaken in the dry season, when only a little stream trickles along its floor, for a young valley by an observer not familiar with the enormous difference between the low- and high-water volumes of rivers in arid regions; but when a master flood comes along, the entire channel will be filled to overflowing. At such times the flood temporarily enlarges the already large channel by lifting silt from the bed, so that the depth of the flood current is added to downward at the bottom as well as upward at the surface, and the downward addition may be even greater than the upward. An extraordinary record of a rising and scouring flood has been made for the lower Colorado at Yuma by the engineers of the U. S. Reclamation Service. An ordinary low-water record shows that the river there stands at 115 feet, gauge height, with a breadth, partly occupied by a 200-foot sand bar, of 480 feet, and a maximum depth of 6 or 8 feet in a main channel about 100 feet wide. During a flood in June, 1921, the river rose to a gauge height of 131 feet, with a breadth of 570 feet, a general depth of 60 feet and a maximum depth of 66 feet in a channel about 300 feet wide. The discharge was then 186,000 cubic feet a second, or 155 times greater than the low-water discharge. The significant item here, in

[19] The Arabic word for river, of which *wady* is the anglicized form, was long ago carried by the Moors into southern Spain, where it still survives in the first syllable of several river names, such as Guadalquivir, Guadalajara, Guadalupe. The interchangeable initial consonants in *guad* and *wady* are also seen in the more Latin words, *guarantee* and *guard*, and their more English doublets, *warranty* and *ward;* also in the French *Galles* for the English *Wales.*

connection with flood-scour of channel beds, is that while the flood surface rose 16 feet, the flood bed deepened 42 feet; that is, the scour was over two and a half times the rise!

Examples of Intermont Troughs and Basins

A typical and valleyless intermont trough-plain, from 10 to 30 miles across and containing several playas, is found in southeasternmost Arizona, where it is known as Sulphur Springs Valley. It is somewhat irregularly bounded on the east and west by mountain ranges of moderate height, believed to be up-faulted blocks, in which numerous valleys have been elaborately eroded; but there are practically no valleys on the plain itself through all its length of over 90 miles. As one travels along its smooth surface, the even horizon appears to recede as it does at sea. Indeed, the curvature of the earth seems to be recognizable there by the appearance of distant cottonwood trees or ranch windmills over the even skyline, before the ground below them comes into sight. The nearly level surface is crossed near its north and south ends by two lines of the Southern Pacific Railway, which run in long, straight-line tangents. The broad surface of this plain is better covered with grassy herbage than is the case with more desert plains farther west. Its general features have been well described in a study of its ground-water supply.[20]

Far to the west in the subhumid climate of southern California, a fine example of a well-enclosed oval intramont basin, in contrast to a long intermont trough, is furnished by San Fernando "Valley," next northwest of Los Angeles. It measures about 25 miles east and west by 12 or 15 miles across, and is surrounded by mountains of moderate or small height on all sides, except for two narrow openings: one on the northeast which is blocked by heavy detrital fans from the higher mountains on the north, and the other on the southeast which remains open. The mountains are, as usual, well dissected by true valleys of erosion, but all the valleys end at the mountain base line, where their channels are continued forward on one radius or another of the laterally confluent detrital fans of low gradient, all of which merge in the central plain of the basin floor. The mountains on the north being higher than the others, their fans are the largest and they push the central plain to an eccentric position near the southern, lower range; and the northern mountains being largely composed of resistant crystalline rocks, the usually dry channels of their long fans supply abundant hard-rock boulders for rock crushers, the high scaffoldings of which are familiar features thereabouts. All the inflow of the wet-weather streams unites at times of flood to form Los Angeles River, which when running finds escape through the open southeastern gap. In the gap stands the growing city of Glendale which, Western fashion, announces its name to the arriving visitor in electric signs hanging over the main thoroughfares, and adds, with the aggressive self-consciousness of new and ambitious Californian cities, "Watch us grow." The San Fernando Plain, a land of arid bush and scanty pasture in its native condition not many years ago, is now largely occupied by towns, orchards, rose gardens and fields; but it has lately been acquired, as a sort of safety valve, by the irrepressible City of the Angels, hence one may expect that in a few years more it will be covered with open-spaced residences and close-set business blocks.

Holes in the Inyo Mountains

Two pronounced examples of exceptionally small, down-flexed desert basins, typically intramont, are found in the

[20] O. E. Meinzer and F. C. Kelton, "Geology and Water Resources of Sulphur Spring Valley, Ariz.," U. S. Geol. Surv. Water-supply Paper No. 320, 1913.

southern part of the long Inyo-White Mountain Range, which rises near the oblique Nevada boundary of California, next east of the Sierra Nevada. One of the basins, measuring only 12 by 5 miles, is known as Deep Spring "Valley," but as it is without outlet it might be better called Deep Spring "Hole," for that expressive term is already officially authorized in naming Jackson Hole in the Rocky Mountains of Wyoming. The hole in the Inyo Range is caused by the down-flexing of a portion of the mountain mass on the northwest against a nearly rectilinear and well-dissected fault scarp on the southeast.[21] The aggraded floor of the hole has an altitude of 4,900 feet, and lies from 1,000 to 3,000 feet below the highlands of the range. Its fans are supplied chiefly from valleys cut in the down-flexed slope on the northwest; and the streams in those valleys work, when they run, as energetically as if their lower courses would lead all the way to the ocean. But they are doomed to early disappointment—they end in a shallow saline lake on the valleyless floor of the hole.

Another deep hole, thirty miles to the southeast in the same range, known as Saline "Valley," is somewhat larger, as its floor measures twenty-five by ten miles. It has a moderately dissected fault scarp of unusual strength on the southwest, which rises fully 6,000 feet over a small lake at 1,000 feet altitude on the floor of the hole. It is difficult to imagine what kind of subterranean movement within the earth's crust can have caused these local cave-ins or failures of upheaval in the Inyo range-block. The collapse of cavern roofs can not be appealed to, because limestones do not enter largely into the make-up of the mountain mass.

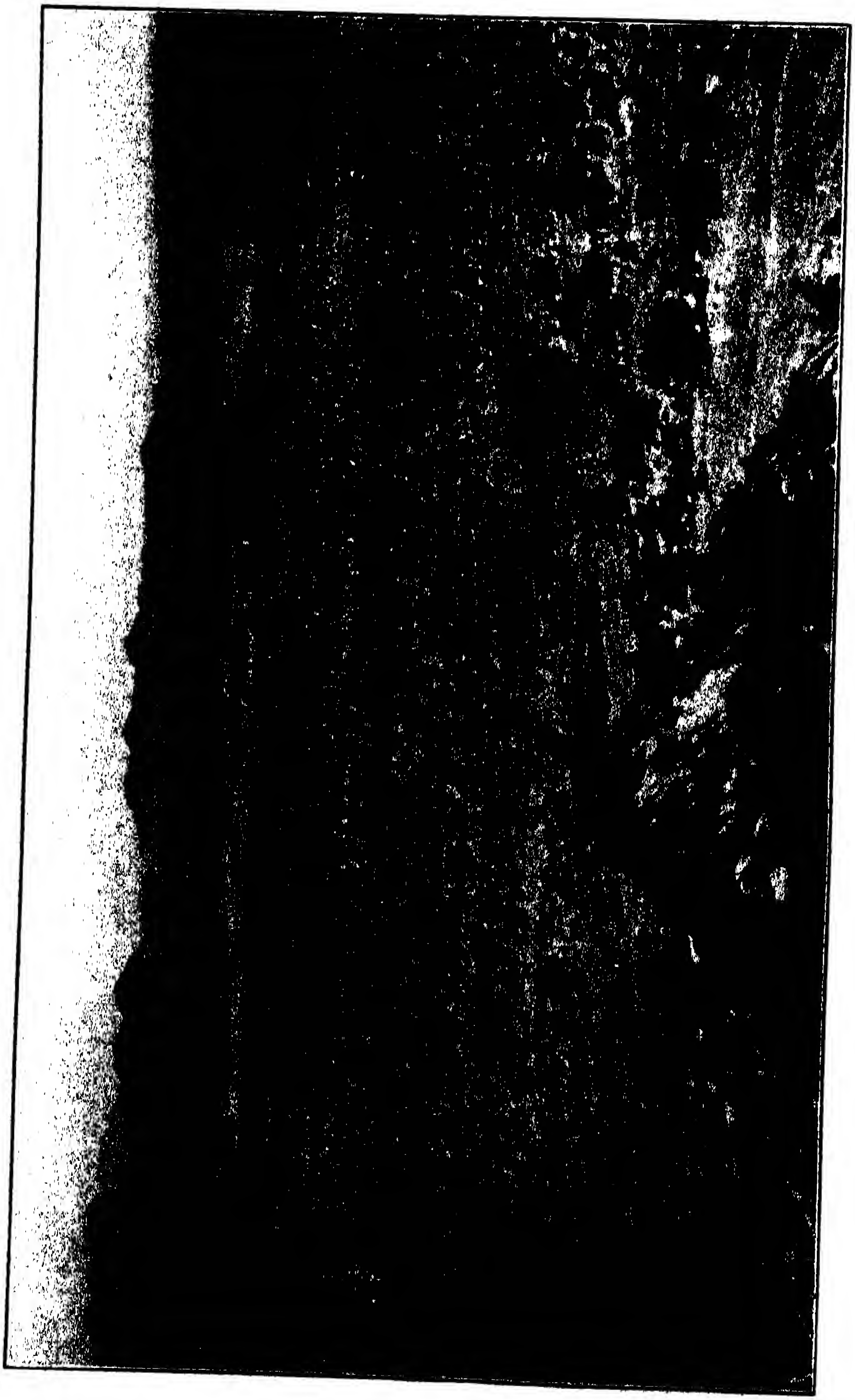
The Great "Valley" of California

The largest example of an aggraded, intermont trough in our Cordilleran country, and one of the best in the whole world, lies beyond the Great Basin in California, where it occupies a down-flexed or down-faulted depression between the lofty Sierra Nevada on the east and the much lower Coast Ranges on the west. It is, of course, known as a "valley," although a French visitor appropriately described it as *la plaine intérieure* over 60 years ago.[22] This magnificent domain, measuring over four hundred miles along its slightly curved length by from 25 to 60 miles in breadth, is a well-defined physiographic unit, for its enclosing mountains are confluent at both ends. It consists, except where the Marysville volcanic buttes rise in its northern part,[23] of a great number of smaller and larger detrital fans of faint slope, between which the axial plain where the fans from the two sides merge lies nearer the lower Coast Ranges, being pushed there by the larger fans from the higher Sierra. The basin is drained by the Sacramento from the north and the San Joaquin from the south to a common westward outlet at the mid-length of the Coast Ranges. Both rivers are valleyless in their course along the plain, and most of their branches are valleyless also, though some of them have excavated shallow valleys of erosion in the upper part of their fans. Until a very late geological period the westward outlet was a trunk river, which may be provisionally named Golden River and which, on its way to the Pacific, ran through gorges of erosion in two Coast Ranges and across an inter-range trough plain between them. In consequence of a slight submergence of its district, the outer gorge is now drowned in the Golden Gate; part of the inter-range trough plain is flooded to small depth

[21] W. J. Miller, "Geology of Deep Spring Valley," *Journ. Geol.*, 36: 510–525, 1928.

[22] E. Friquet, "Coup d'oeil sur la constitution géologique . . . de la Californie . . .," *Bull. Soc. Géol. France*, 23: 347–371 (see p. 365), 1867.

[23] Howel Williams, "Geology of the Marysville Buttes, California," *Univ. Calif. Geol. Bull.*, 18: 103–220, 1929.



Photograph by E. D. Wilson, Arizona Bureau of Mines

ISOLATED MOUNTAINS AND VALLEYLESS AGGRADED PLAINS

IN THE DESERT OF SOUTHWESTERNMOST ARIZONA. THE LINES OF BUSHES INDICATE THE COURSE OF DRY WASHES.

in San Francisco Bay, and the inner gorge is drowned in Carquinez narrows, above which the shallower waters of Suisun Bay overlap part of the inner Great "Valley" plain. The shallow Suisun overlap was originally larger than at present, for it has been much encroached upon by the double delta of the two betrunked rivers.

The great interior plain was a grazing region under Spanish-Mexican dominion; it became a farming country in the early days of California's statehood; it is now largely a fruit country. An extensive area in its northern part has been elaborately mapped by the topographers of the U. S. Geological Survey on a scale of two inches to a mile, with five-foot contours. One of the most interesting items in the recent history of the plain, an item intimately connected with its valleyless form, is the conflict between the farmers on the plain and the miners on the adjoining uplands of the Sierra Nevada. The latter "hydraulicked" the auriferous gravels of the uplands so actively during the third quarter of the last century that the farmers' fields along the valleyless rivers were in danger of being buried under the artificially increased outwash of detritus. Action through the courts to avert this danger was sought by the farmers and secured in 1884, and in 1893 a California Débris Commission was appointed by Congress to safeguard the nominally navigable rivers from obstruction by the downwashed "tailings." A quantitative study of the gravel outwash and of its aggradational effects down stream from the hydraulicked uplands, where the scars of the washing are still prominent features of the Sierran landscape, was one of the latest investigations undertaken by Gilbert.[24]

[24] G. K. Gilbert, "Hydraulic-mining Débris in the Sierra Nevada," U. S. Geol. Surv. Prof. Paper 105, 1917.

An Orange Belt in Southern California

A smaller but good-sized and heavily aggraded intermont or perhaps intramont trough, some sixty miles in length, lies in southern California. Its northern border is formed by the high, east-west San Gabriel Mountains and their eastward extension, beyond the curious oblique depression known as Cajon Pass, in the San Bernardino and San Gorgonio Mountains. Its southern border, 10 or 15 miles away, is formed by an irregular series of uplands and mounts of moderate altitude. A series of great detrital fans slant southward from the loftier northern range; they are relatively steep, coarse textured and dry near their heads, but become nearly level, fine textured and moist at their far ends, ten miles or more forward. The fans from the southern uplands are relatively small; hence the physiographic axis of the trough is pushed close to its southern margin; and there runs the Santa Ana, usually of reduced volume yet the largest river in the southern part of the state. It has, for much of its length, cut a shallow valley in the trough floor, probably because of its recent success in trenching a gorge through the low range of the Puente Hills, which encloses the trough on the west. But when Californians speak of the "Santa Ana Valley" they do not refer to this little valley of shallow excavation, but to the heavily aggraded trough-plain in which the little valley is eroded.

The trough floor was, in its native state, not many years ago, an unproductive waste, an "idle wild." It has been rapidly converted by intensive cultivation into one of the most fruitful districts of our entire country, and is now occupied by an exceptionally well-conditioned population. San Bernardino, Riverside and Redlands are near its east end; the unusually beautiful city of

Pasadena is at its west end, with Los Angeles beyond low hills ten miles to the southwest. Many smaller communities occupy intermediate situations. The long fans are largely covered in their upper half with orange groves, which are irrigated with ground water pumped up from the coarse detritus of the fan heads. Much of the lower, and nearly level, distal extension of the fans, where the water-table is near the surface, is farmed, but the lower part of some of the eastern fans, where the surface is exceptionally sandy, is occupied by "the largest vineyard in the world," one of California's best-justified superlatives.

No Aggraded Basins in the East

In the northeastern states, north of the Missouri and the Ohio rivers, many plains were built up over an uneven land surface during the Glacial period. Some of them are plains of till, which may be regarded as delta-sheets formed beneath the thinning margin of ice-sheets, where more detritus was brought than could be dragged farther forward. Others are gravel and sand plains, formed where outflowing streams of ice-water deposited part of the detritus that they had gathered in their subglacial courses. There are also many small plains formed by the inwash of detritus into little lakes of glacial origin. These plains are purely climatic in origin, not at all orogenic.

There are, indeed, no recently down-faulted and aggraded basins in the East such as those above described and many others like them in the West. The only approach to an Eastern homologue of the Western basins is found in the small, shallow, water-filled hollows, known as "sunk lands," that were formed by slight subsidences, perhaps due to deep, cavern-roof collapses, in the northern part of the Mississippi flood plain at the time of the earthquake of 1811, of which Fuller has prepared an admirable account.[25] Two of the hollows hold lakes: Reelfoot, 13 miles long, in northwestern Tennessee; and St. Francis, over 25 miles long, in northeastern Arkansas; both are of trifling depth. The great Mississippi flood plain itself, in which these sunk lands occur, is in certain respects analogous to the axial flood plains of the Sacramento and San Joaquin rivers in the Great "Valley" of California; but in other and more important respects the flood plains are unlike. That of the Mississippi is the smooth floor of a true valley of erosion in the Gulf coastal plain, which gained great width between its limiting valley-side bluffs on the east and west by reason of the great size of the river that eroded it; and that river was, for a time, doubly great, because during the invasion of our northern states by Canadian ice-sheets they constrained a great part of the drainage, which normally belongs to the St. Lawrence and Hudson Bay River systems, to flow southward via the lower Mississippi to the Gulf of Mexico. Although small areas of outwashed deposits are formed along the base-lines of the bluffs on the east and west by the streams that there descend from the enclosing uplands, these deposits do not by any means dominate the course of the Mississippi as the courses of the Sacramento and San Joaquin are dominated by the fans outwashed from the Sierra Nevada and the Coast Ranges, but on the contrary the Mississippi, by means of the lateral slopes of its own flood plain, dominates the small streams and tells them to sidle along the base of the bluffs until it is ready to come over and take them in. The Yazoo, nearly 200 miles in length, is the type for the world of such a stream. The Mississippi picks it up at Vicksburg.

[25] M. L. Fuller, "The New Madrid Earthquake," U. S. Geol. Surv. Bull. 494, 1912.

See also, W. A. Nelson, "Reelfoot—an Earthquake Lake," *Nat. Geogr. Mag.*, 45: 95–114, 1924, with fine airplane views.

Long Duration of Arid Erosion

In spite of the usual inactivity of streams in desert regions, they work with enormous energy when flooded and then accomplish a vast amount of erosion, transportation and deposition. This may be seen not only in the deep valleys that they have excavated in many mountain ranges but also in the construction of the great detrital fans along the mountain bases. Scores of thousands of years must have been thus occupied, for the fans were largely formed before the last Glacial epoch, as is thus known: During the moister climate of that time the northeastern part of the Great Basin was occupied by an extensive lake, nearly as large as the present Lake Michigan, to which the name of Bonneville has been given after the first explorer who recognized its high-level shore lines, reference to which has already been made. Great Salt Lake, a mere film of extremely saline water, now reserves for itself a relatively small part of the dried floor of Bonneville in the more arid climate of the present day. The shore lines of the extinct greater lake are strongly marked on the rocky flanks of several basin ranges where its waters were deep, as in the neighborhood of Salt Lake City, up to nine hundred feet above the present lake level. But in the shallower southern arms of Bonneville, where wave action was weak, the shore lines are lightly marked even on the detrital piedmont fans. Many of these faintly shore-scored fans are of great size; hence they must have almost reached their present size in pre-Bonneville time, and that time must therefore have been characterized by a fan-building or desert climate, like that of to-day, for a much longer duration than the post-Bonneville period, as was long ago made clear by Gilbert.[26] Discontinuity of valleys has therefore long been characteristic of the Great Basin region.

[26] G. K. Gilbert, "Lake Bonneville," U. S. Geol. Surv. Monogr. I, see pp. 91, 92, 1890.

Hanging Valleys in Fault-block Mountains

The most remarkable examples of discontinuous valleys in the Great Basin remain to be described. They are to be seen, opening at high levels above the adjoining trough floors, in the east-tilted Funeral and Panamint fault-block ranges that enclose the exceptionally low-lying Death Valley in southeastern California. Their origin appears to be essentially as follows. During an earlier episode in the history of these ranges, an episode characterized by a still-stand pause after partial up-faulting, well-opened valleys were carved in their flanks and appropriately large detrital fans must have been built forward in the adjoining down-faulted troughs, as in the background of Fig. 4. Since then a second episode has been introduced at a recent date by a further up-faulting of the range blocks and a further down-faulting of the troughs along much of their length, as in the middle of the figure. In consequence of the renewed movement the well-opened valleys, that were carved back of the original fault scarp during the previous episode of quiescence, now open into the air and have sharp clefts cut below their hanging mouths, while the depressed fans are buried under an accelerated discharge of detritus from the slightly steepened back slope of the range on the other side of the trough, as in the foreground of the figure. The little fans at the base of the new-cut clefts are manifestly much too small to contain the detritus that was eroded and removed in the excavation of the well-opened hanging valleys. Hanging valleys, opening into the air, are discontinuous with a vengeance! A greater contrast than that which they present with the steady-going Appalachian valleys can hardly be imagined. And clearly, the cause of the contrast is not to be found in any lack of mobility in the Western streams, when they are wet enough to run, but in an

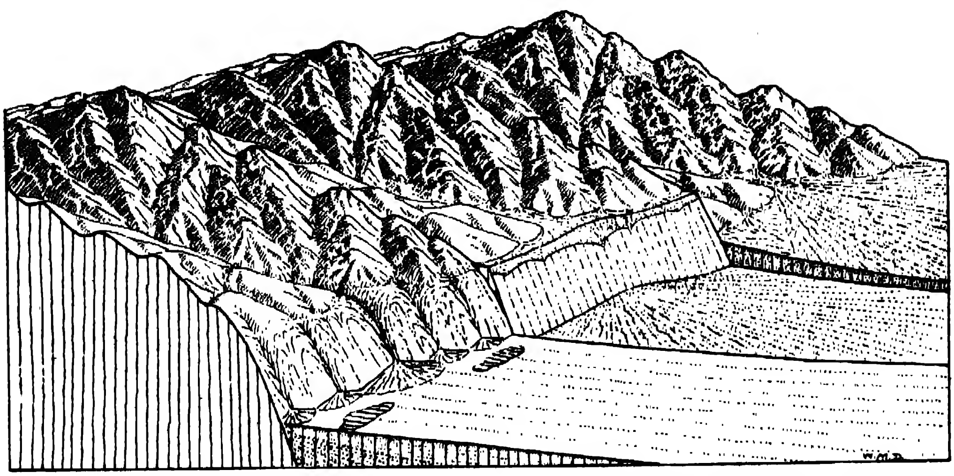


FIG. 4. A THREE-STAGE DIAGRAM TO SHOW THE EVOLUTION OF A HANGING, FAULT-BLOCK VALLEY

IN THE BACKGROUND, A MATURELY ERODED FAULT BLOCK, WITH A LARGE FAN OUTWASHED FROM ITS CHIEF VALLEY INTO THE ADJOINING DOWN-FAULTED TROUGH. IN THE MIDDLE, THE POTENTIAL FORM OF THE SAME, AFTER FURTHER UP-FAULTING OF THE MOUNTAIN BLOCK AND DEPRESSION OF THE TROUGH; A SLANTING FAULT SCARP SEPARATES THE TWO PARTS. IN THE FOREGROUND, THE SAME AFTER EROSION AND DEPOSITION CONSEQUENT ON THE RENEWED FAULTING.

excess of mobility in the Western earth crusts. The sight of these young fault scarps under the hanging valleys makes one realize how wild the West still is, geologically, and how utterly unlike the geologically tamed East.

Where renewed up-faulting of this kind has recently taken place, the physiographic axis of the associated down-faulted trough lies for a time close to the scarp base of the uplifted block, as may be known from the occurrence there of salt marshes which ordinarily lie near the mid-line of the trough.[27] Between the cut-off valleys, now high in the air, and the alluvial cover of the depressed and buried fans, stands the newly exposed and little modified fault scarp of bare rock, which in Death Valley is inclined at an angle of 40° or 45° and measures from 500 to 1,000 feet in slanting height. The scarp transects the rock mass without regard to its complicated structure. The little detrital fans that have been built out on the new floor of the trough at the base of the fault-scarp clefts are, as above noted, of small volume compared to that of the high-standing valleys. A front view of some of the high valleys, narrow clefts and little basal fans suggests their likeness to the bowl, stem and base of a goblet. Be it noted, however, that, although many valleys are thus very distinctly truncated by renewed faulting in the Funeral and Panamint ranges, they are not so sharply cut off as are the numerous hanging lateral valleys above the glacially overdeepened fiord troughs of Alaska or Norway, or as the *valleuses* that open abruptly in the sea cliffs of Normandy at mid-height above the cliff base; but they are more sharply cut off than the hanging valleys of Kentucky, above described, and they are certainly

[27] The recent and temporary displacement of trough-floor marshes or lakes has been described by A. C. Lawson in his account of certain modern faults along the east base of the Sierra Nevada, not far from Reno: *Bull. Seism. Soc. Amer.*, 2: 195, 1912. Another example is described by R. J. Russell in his account of the Warner Range of Northeastern California: *Univ. Calif. Bull. Geol.*, 17: 483, 1928.

astonishingly out of gear with their surroundings.

Various other examples of renewed faulting in fault-block ranges might be instanced of small or large measure. The most significant signs of small upfaulting are seen in low "eyebrow scarps," from 10 to 20 or 30 feet in height, cutting across piedmont detrital fans, somewhat as in Fig. 5. They run parallel with but stand somewhat forward from the base line of a fault-block mountain.[28] The subsurface displacements involved in the production of these low scarps cause earthquakes, as is already known from three historic examples, in spite of the shortness of our Western historic record. One was in Owens "Valley" at the eastern base of the Sierra Nevada in southeastern California,[29] this grand mountain range being the largest and perhaps the most irregularly complicated fault block in the West. The view of the tremendously dissected scarp in the southern part of the range from half height on the western flank of the Inyo Range across the intervening trough of Owens "Valley" is one of the grandest prospects that our country affords. Another quake-producing fault scarp was formed in 1887 in Sonora, Mexico, just south of Arizona, where its face averaged eight feet in height for nearly forty miles. A third was produced in Nevada in 1915.[30]

It is worth adding that eyebrow scarps are, like the fault-block mountains with which they are so closely associated, an American contribution to knowledge; and also that when Gilbert, their discoverer, showed an excellent one in the

[28] Many examples of recent fault scarps in piedmont detritus, variously complicated, are described by G. K. Gilbert, "Lake Bonneville," U. S. Geol. Surv. Mon. I, see pp. 343–355, 1890. Other examples are given by I. C. Russell, "Lake Lahontan," *ibid.*, Monogr. XI, see p. 275, 1885; also by A. C. Lawson, "The Recent Fault Scarps at Genoa, Nevada," *Bull. Seism. Soc. Amer.*, 2: 193–200, 1912.

[29] J. D. Whitney, "The Owens Valley Earthquake," *Overland Monthly*, 9: 130–140, 266–278, 1872.

[30] G. E. Goodfellow, "The Sonora Earthquake," *Science*, 11: 162–166, 1888; J. C. Jones, "The Pleasant Valley (Nevada) Earthquake of October 2, 1915," *Bull. Seism. Soc. Amer.*, 5: 190, 1915.

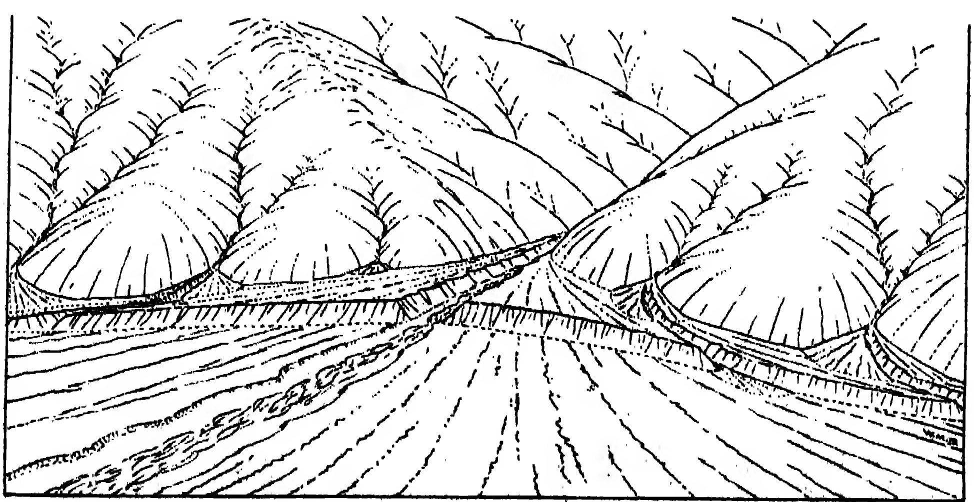


FIG. 5. A FAULTED ALLUVIAL FAN AT THE MOUTH OF A VALLEY IN A MATURELY DISSECTED FAULT-BLOCK MOUNTAIN. IN CONSEQUENCE OF A RECENT RENEWAL OF FAULTING, THE FAN IS TRAVERSED BY AN "EYEBROW" SCARP.

neighborhood of Salt Lake City to a party of European geologists who were touring the West after the International Geological Congress at Washington in 1893, the scarp was so great a novelty that they one and all refused for two days to accept his interpretation of it as the result of a recent fault: to them it was only "a gravel bank."[31]

Renewed faulting, of less recent date than in Death Valley but of much the same amount, has taken place in the great up-faulted, west-facing crustal block known as the Wasatch Range in Utah, at a point 15 or 20 miles north of Salt Lake City. The previously well-dissected and degraded mountain mass was there subrecently upraised and the large fans that must have fronted its well-opened valleys were depressed. The inferred fans are now out of sight under the piedmont alluvial lowland which borders Great Salt Lake; the broadly opened mountain valleys and the rolling uplands and highlands between them stand from 500 to 1,000 feet above the lowland. Sharp-cut gorges have been sliced in the battered fault-scarp below the uplifted valley mouths, from which small fans of a second generation are now growing.[32] An exceptional example of renewed fault-block upheaval is found in the long, heavily louderbacked Galiuro Range of southeastern Arizona, for there the detrital deposits, built forward from the flanks of the range after its first upheaval, have been raised with the range in its second upheaval and now share its renewed erosion.[33]

[31] "Biographical Memoir of G. K. Gilbert," Mem. Nat. Acad. Sciences, XXI, see p. 102, 1926.

[32] G. K. Gilbert, "Studies of Basin Range Structure," U. S. Geol. Surv. Prof. Paper 153, see p. 50, 1928.

[33] W. M. D. and Baylor Brooks, "The Galiuro Mountains, Arizona," *Amer. Journ. Sci.*, 30: 89–115, 1930.

Aridity, Detrital Fans and Irrigation

In consequence of its arid climate the great Southwest must irrigate its fields and orchards on the intermont detrital plains, and here the valleyless character of the plains is of great advantage. The streams from the larger mountain valleys are taken in hand at the valley mouths and led along major and minor distributing canals on the low-grade piedmont fans, the gentle, radial slopes of which are admirably adapted to this method of refreshment. Hence although the aridity of the region imposes the necessity of artificial watering before crops can be raised, it also provides, as if by way of compensation, a peculiar, valleyless land form on which artificial watering can be most easily accomplished; for, as above told, valleyless detrital fans are a characteristic, indeed, a necessary consequence of arid erosion in a mountain-and-plains region. The Mormons, our earliest settlers in the desert wilderness, industriously established their village communities wherever a suitable combination of mountain stream and piedmont fan could be found, and not a few of these communities years ago reached the maximum population that can gain a livelihood from the fields which they irrigate from the fan-feeding mountain valleys. Some of the communities utilized the high-level, mountain-flank deltas that were built up in the waters of Lake Bonneville; and inasmuch as all such deltas are now trenched by the streams that built them, their occupation demands a certain amount of engineering in the construction of canals which divert the streams some distance back in the mountains and lead them in canals of low gradient along the valley-side slopes to the high-standing delta plains.

All later settlers in the dry country follow the Mormon example. In recent years the U. S. Reclamation Service has, by building great dams to enclose large

reservoirs, greatly increased the area of the detrital plains upon which the rain-water falling on the mountains is now spread. But unhappily these beneficent projects have not always brought success to those who have striven to take advantage of them; the outlay involved before any profitable returns could be secured has proved ruinous to many a well-intentioned but ill-informed settler.

The Roosevelt Reservoir and the Phoenix Oasis

The Roosevelt Reservoir in east-central Arizona may be taken as a type example of its kind, for although its reservoir is not the largest that has been impounded, its irrigated area is said to be the most flourishing of all the Western reclamation projects. The reservoir is enclosed by a masonry dam which blocks a narrow, crosscut gorge in a fault-block mountain range, and there the united waters of Salt River from the highlands on the southeast and of Tonto Creek from the ranges to the north are held up in a great lake, 35 miles in length when filled to overflowing. The conserved waters are discharged westward along Salt River Valley, eroded through a well-dissected mountainous belt, largely composed of tilted lava sheets and ash beds, for some 30 miles to a broad intermont trough, where the river had through previous ages built up a broad, faintly sloping, detrital fan of 40 miles radius and of as great a frontal spread in its extension into the desert. It is upon this naturally graded detrital surface that a large area around Phoenix, the capital of the state, has been developed into a great oasis; but instead of bearing that appropriate name, the irrigated area is known as "Salt River Valley." That title is most unfitting, for it is wholly because of the unvalley-like convexity of the fan that irrigation has there been so economical and so successful. One might as well call the Mississippi Delta a valley, where it projects into the Gulf of Mexico! It is precisely because the real Salt River Valley of erosion ends at the mountain border and that the river thence onward runs, Western fashion, on a valleyless fan that the oasis was there located; and in order to tell the truth about this wonderful district a careful use of the old term, valley, is advisable.

A peculiar feature of the Salt River fan is that several partly buried mounts and knobs raise their heads through it. One of them is the small Tempe Butte, close to the river a few miles below its exit from the mountain country; it is said to have been named by an imaginative English remittance man, who fancied that he saw from its top a prospect that resembled its classical patronymic. Another and much larger emergent mass is Dromedary Mountain, a ridge of red sandstone, whose imitative head-knob and back-hump are pointed out to every visitor for deserved admiration. Largest and farthest forward is the low Salt River Mountain group, apparently an uplifted and dissected fault block; and beyond it, in the trough between that group and the longer Estrella fault block, flows the slender Gila River. Salt River now makes its junction with the Gila northwest of the emergent mountains, but in the past it has sometimes joined the Gila on their southern side. Thus it repeats on a small-scale, inland fashion, the shifting behavior of the great Hwang-ho, in almost tenfold larger relation to the coastal mountain mass of Shantung in China.

Salt River at present trenches a shallow valley in its fan for about four miles below the fan head at the border of the broad mountain belt from which it issues; hence the Granite Reef distribution dam has been built on a rock ledge at the mountain base line, so as to raise the water to a level from which it may be led in canals, with a gradient of about

18 inches to a mile, out upon the fan surface either side of the apex trench. Other canals then branch off on several fan radii as they are extended. Farther on, low locks are provided to check the canal flow. Innumerable ditches carry water to the fields, all of which, as well as the roads between them, are laid out in squares on the lines of the National Land Office Survey. The natural washing of the fan by local rains as well as by mountain floods has provided so smoothly and gently sloping a surface that no regrading is necessary when the canal water reaches the fields. The field ditches usually run along plow furrows parallel to the field sides, but the more careful farmers plow their fields obliquely, on just such a gradient as is suited for their special crops. Water distribution is regulated by an official ditch-man or *zanjero,* a name that, like many others in the Southwest, records the earlier time of Spanish-Mexican occupation. A water supply for the farther fields is secured in part by pumping up the excess of underflow from the fields nearer the fan apex; and the pumps are driven by wire from an electric power plant at the main dam, which, when the reservoir there is full enough, also supplies power to Phoenix and several smaller cities as well as to a number of mining towns in the mountains.

Favorable as are the natural conditions here provided for irrigation, it is by no means the case that every arriving farmer has made a success of his enterprise. "Lungers" from Eastern cities seem sometimes to have thought they could suddenly transform themselves from office clerks into successful chicken ranchers; there are said to be a good number of ranches held by Phoenix banks on foreclosed mortgages. Yet on the whole so great a measure of profit has been reached that the water-users themselves have, on their own responsibility, added two new dams and are about to add a third between the Roosevelt and the Granite Reef dams, in order to provide extra storage for the rainfall of wet years which would otherwise overflow to the Gila and be wasted, and thus preserve so much of it as does not fly off by evaporation for local use in drier years. It is truly a delightful experience for the traveler, after he has crossed weary miles of dry country—where scattered range cattle are sometimes so near starvation in their search for spindly tufts of grass close under the stems of creosote bushes that they try to eat the spiny "cholla" and fill their muzzles with needle-like thorns—to come upon the verdant rectangles of the broad oasis and see compact herds of happier cattle pasturing up to their knees in alfalfa fields or resting, sated, in the shade of leafy cottonwoods. No wonder Arizonans are proud of the oasis; but I do wish they would not call it a "valley."

Some Great Basin Rivers Are Continuous

Condensed generalizations about a region so large as the Great Basin are dangerous if taken alone, but safer if diluted with exceptions. The first exception to be here introduced modifies the statements made above as to the discontinuity of the rivers in the dry country; but let it be noted that the very need of excepting the few long, through-flowing rivers from the many that run dry and fall short proves that river discontinuity is still the rule. The Colorado is, as already intimated, the chief exception, evidently because its headwaters are well fed by the rains and melted snows of the Rocky Mountains, and its valley, although heterogeneous, is almost as continuous as the river flow. But like the Nile and certain other rivers which, rising in wet regions, venture to cross deserts on their way to the sea, the Colorado is of diminishing volume in its lower course.

The slender Gila is next in order, with a length of about 400 miles. It rises in western New Mexico and crosses part of that state and all of Arizona on its way to join the Colorado; Yuma stands at the junction. Although thus succeeding, at least while high-water lasts, in reaching a trunk river that flows to the sea, the Gila is extremely variable in volume, being subject to rapid rise in "flash floods" and to almost as rapid fall. In dry seasons its volume varies irregularly along its course, according as inflow or evaporation takes the upper hand.

A third river of fair length is the Humboldt in northern Nevada, but it measures only 250 miles and its flow is even more variable and uncertain than that of the Gila. There is no fourth that need be mentioned here.

Valleys in Intermont Trough Plains

A second exception concerns the occurrence of valleys of erosion in aggraded troughs and basins. It not infrequently happens that the rock-bound valleys of Basin Ranges are continued by their intermittent streams for a short distance and with a small depth in the steeper, proximal slope of the piedmont fans, but the valleys usually vanish before the flatter distal slope is reached. It is much more rarely the case that the whole area of an intermont basin or trough in the Great Basin is dissected by the ramifying branches of an outflowing river, although such dissection is common in the Rocky Mountains, as has already been told. Among the not numerous cases of this kind are certain basins drained by the Gila, where it traverses the mountainous belt of Arizona between the plateau country of the northeast and the lower-lying and more desert country of the southwest. For although the lower course of this river avoids the difficult task of range-trenching by running around the mountains and keeping to the interweave of circummont aggraded trough plains, it most enterprisingly cuts deep canyons through a number of ranges in the upper half of its course; and there it is now well advanced in the work of carrying away the detritus from valleys eroded by its branches in the plains that occupied the inter-range troughs before the cross-canyons were cut so deep as they are now. This suggests that the river is, in spite of its slenderness, of antecedent origin, and that although compelled to aggrade the down-faulted troughs while faulting was in progress it succeeded in holding its course across the rising ranges. The fact that the trough filling is for the most part gravel and sand rather than fine silt shows that the troughs were not as a rule occupied by lakes.

A fine example of this kind, worthily studied and described by Ransome, is found in Dripping Spring "Valley," between the Mescal and the Dripping Spring fault-block ranges in southeastern Arizona.[34] When one sees the heavy limestones in which the Gila has cut its canyons up and down stream from this trough, one must marvel that so small a river could have mastered the uprising of blocks so massive and of rocks so resistant. The Coolidge Dam, lately completed, is built in the deep canyon of the Gila up stream from the trough through the great monocline of the Mescal Range.

The valley of the San Pedro, a north-flowing stream of very variable volume, which joins the Gila next down stream from its canyon at the south end of the Dripping Spring Range, is of somewhat different origin. The braided channel of its sandy wash lies a little below a flood plain with a width of about a mile, and the flood plain has been excavated, probably in consequence of a rather broad up-raising of the district (associated with the above-mentioned second

[34] F. L. Ransome, "Ray Geologic Folio," U. S. Geol. Survey, 1923.

upheaval of the Galiuro Mountains not far to the east), to depths of a few hundred feet, more or less, along the axis of a heavily aggraded intermont trough. In consequence of this excavation, the detrital slopes of the trough have been strongly dissected by the wet-weather streams that come down from the enclosing mountains. The San Pedro trough thus differs markedly from its neighbor, the Sulphur Springs trough, over the mountains to the east, which is as yet not at all dissected.

While the San Pedro trough was filling up, during and for a time after the most active faulting of the enclosing ranges, no longitudinal stream could have existed here, for the fine-textured deposits along the trough axis commonly contain lenses of gypsum, which imply the occurrence of many saline water sheets, separated by advancing fans, rather than of a continuous, north-sloping wash. Since then, and probably in consequence of a warping upheaval of later date as above suggested, the continuous longitudinal valley of to-day has been eroded and the trough slopes have been well dissected. The contrast between the dissected benchland of the trough sides and the true valley excavated beneath them along the trough axis is clearly recognizable, but both are included under the single name, San Pedro "Valley," by the few residents.

Worn-down Intermont Troughs

Although the plains which occupy the intermont troughs of the Great Basin ordinarily have every appearance of being built up or aggraded with detritus from the adjoining mountains, as above set forth, a certain number of them have been found to be not filled-up but worn-down plains, for their comparatively smooth surface bevels across the tilted edges of imperfectly consolidated gravels, sands and silts, as conventionally shown in the foreground of Fig. 6. The meaning of these worn-down plains appears to be essentially as follows. The broadly degraded prefaulting surface of the region—the Powell surface—appears to have been somewhat irregularly and perhaps repeatedly warped; whereupon degradation continuing on the up-warped areas supplied detritus which was strewn in stratified deposits over the down-warped areas, thereby forming what may be called "supernumerary beds." When the time for block-faulting came, these beds were tilted up with the underlying rock mass, thus giving a potential surface shown in the rigid background of Fig. 6, in which the inter-block trough angle stands above the level down to which erosion may there operate. In consequence of such displacement the weaker supernumerary beds have been rapidly reduced to a nearly plain surface; they now survive only in the low-lying "safe corner" of the inter-block angle, while the harder rocks, stripped of their weak cover and more or less dissected, still stand up boldly in dissected mountain ranges, as shown in the foreground of the same figure. In cases of this kind the trough-floor plain is not a surface of aggradation but of degradation. The number and distribution of degraded trough-floor plains is not yet known. They have been recognized by various observers; a recent account of a number of them has been given by Blackwelder.[35]

Piedmont Rock-floors or Pediments

A third exceptional feature of the Great Basin is found in certain broad, gently sloping rock floors or "pediments," which have been worn down by far-advanced arid degradation, as illustrated by the change from the potential background to the greatly reduced foreground of Fig. 7. When seen in distant

[35] Eliot Blackwelder, "Origin of the Desert Basins in the Southwestern United States," *Bull. Geol. Soc. Amer.*, 39: 262–268, 1928.

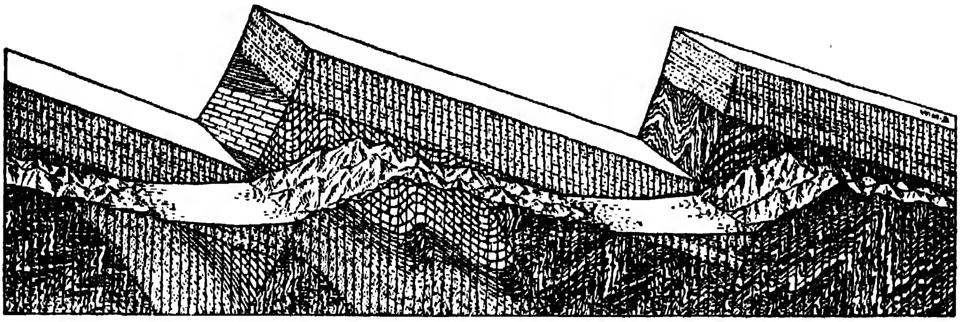


FIG. 6. DIAGRAM TO ILLUSTRATE THE ORIGIN OF WORN-DOWN, INTER-RANGE GRAVEL PLAINS

IN THE BACKGROUND, THREE UP-FAULTED "GILBERT" BLOCKS IN POTENTIAL (NON-ERODED) FORM, EACH BLOCK HAVING A HEAVY COVER OF LITTLE CONSOLIDATED GRAVELS AND SANDS UNCONFORMABLY OVERLYING THE "POWELL" SURFACE, PREVIOUSLY WORN DOWN ON THE RESISTANT AND DEFORMED ROCKS OF THE "KING" MOUNTAINS. IN THE FOREGROUND, THE SAME, REDUCED BY EROSION DURING AND AFTER FAULTING TO PRESENT FORMS, IN WHICH THE WEAK, COVERING BEDS ARE WORN DOWN TO INTER-RANGE PLAINS AND THE RESISTANT ROCKS ARE CARVED INTO MOUNTAIN RANGES.

profile, the almost rectilinear slope of these rock floors is surprisingly graceful and pleasing. All direct evidence of block faulting has disappeared from these residual mountains, and faulting is supposed to have taken place in their earlier history only because other less-consumed mountains in the same district are more manifestly of such origin. The worn-down, hard-rock pediments are comparable with the worn-down, inter-mont plains described in the preceding section; but the two kinds of worn-down plains differ in that those which are degraded on little consolidated detrital deposits may be associated with still vigorous ranges, while those degraded on the hard rocks of the ranges are, *ipso facto,* associated with subdued, dying-out ranges.

A particularly good example of a worn-down rock pediment is found

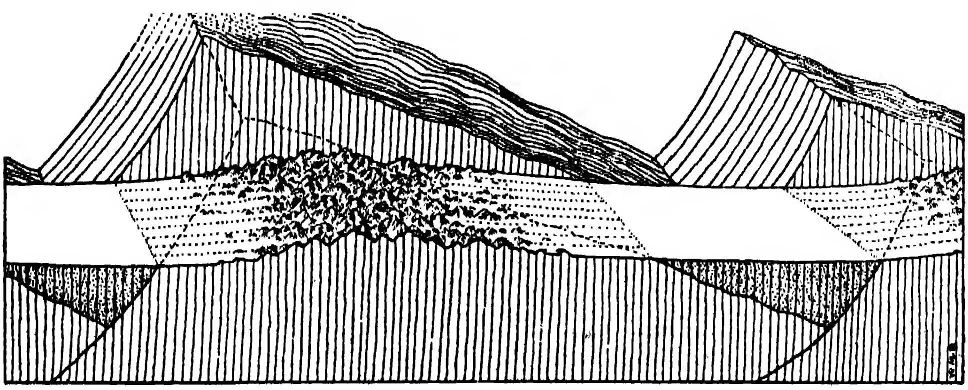


FIG. 7. DIAGRAM TO ILLUSTRATE THE ORIGIN OF WORN-DOWN ROCK FLOORS AROUND RESIDUAL MOUNTAINS

IN THE BACKGROUND, TWO UP-FAULTED BLOCKS IN THEIR POTENTIAL (NON-ERODED) FORM. IN THE FOREGROUND, THE INTER-BLOCK DEPRESSIONS ARE AGGRADED IN DETRITAL PLAINS AND THE UP-LIFTED BLOCKS ARE GREATLY WORN DOWN TO SUBDUED MOUNTAINS, FLANKED BY SMOOTH ROCK FLOORS (PEDIMENTS) WHICH GRADE IMPERCEPTIBLY INTO THE DETRITAL PLAINS.

around the low Sacaton Mountains, some 40 miles south of Phoenix, Arizona. Here the dwindling mountains and their isolated outlying knobs appear to be greatly reduced remnants of a formerly larger and much higher mass, which was very likely of fault-block origin, like the still vigorous Estrella Range, a score of miles farther northwest. The Sacaton pediment has a forward slope measuring several miles in radial length, with a declivity of 4°, 3° or only 2°. It is variably veneered with sands and gravels. The existence of worn-down rock floors was made known by McGee, some forty years ago.[36] Further account of them was later given by Paige.[37] The fullest explanation of their origin is to be found in a masterly deductive analysis of the processes and products of arid erosion by Lawson[38] and an appreciative explanatory description of a number of typical examples has been prepared by Bryan.[39] A comparison of these greatly degraded and almost bare rock floors of greatly degraded mountains in desert regions with the soil-covered rock floors of greatly degraded highlands in humid regions is the subject of one of my own recent essays.[40]

Some Southwestern, circummont rock floors are a little dissected by shallow valleys, perhaps in consequence of a slight change in climate, but most of them are as valleyless as the detrital slopes and playas to which they gently slant down. Their valleyless condition is, however, of quite unlike origin from that of aggraded detrital slopes. On those slopes no valleys ever existed; during all their aggradation they have been traversed only by wet-weather stream channels or washes. But the development of the rock floors was begun by the erosion of true, rock-walled valleys in the original mountain mass, and it was completed by the consumption of the inter-valley rock-ridges until nothing but a rock plain was left. Such a plain might therefore be regarded as the last member of a series of forms all the earlier members of which are valleys in a young, mature or senile stage of evolution, but the last and most senile member of the series, being without enclosing slopes, falls out of the class of valleys and enters the class of plains.

Brief descriptions having now been given of the chief exceptional features which depart from the more prevalent forms of the Great Southwest, the lava plains of the Northwest must have brief mention.

The Lava Plains of the Northwest

Just as the formerly glaciated and now deglaciated region of the northeastern states has been excepted from the general statements made at the beginning of this essay regarding the mature continuity of valleys over the Atlantic two thirds of our country, so now an extensive lava-covered region which stretches to the north of the Great Basin almost as far as the international boundary must be excepted from most of the foregoing statements regarding the Pacific third of our country. There a preexistent land, probably of mountainous form, has been buried by volcanic outblowings of shattered lava or "ash" and by volcanic outpourings of molten lava to depths of hundreds or thousands of feet. The land surface very likely subsided slowly while the lava cover accumulated upon it. Ages must have elapsed during the growth of this heavy igneous shroud, for the petrified remains

36 W J McGee, "Sheet-flood Erosion," *Bull. Geol. Soc. Amer.*, 8: 87–112, 1897.

37 Sidney Paige, "Rock-cut Surfaces in the Desert Ranges," *Journ. Geol.*, 20: 442–450, 1912.

38 A. C. Lawson, "Epigene Profiles of the Desert," *Univ. Calif. Geol. Bull.*, 9: 23–48, 1915.

39 Kirk Bryan, ". . . The Papago Country, Arizona," U. S. Geol. Surv. Bull. 730, 1923.

40 W. M. D., "Rock Floors in Arid and Humid Climates," *Journ. Geol.*, 1930.

of forest trees are found in various ash beds which alternate with the lava sheets. Longer ages must have elapsed since the later sheets were outspread, for part of the lava-shrouded region has been strongly deformed and its upraised lava cover has been worn down to low relief again. But in other parts the lava sheets are so recent that their surface, often retaining a ropy flow structure, banks against the adjoining mountain slopes just as the waters of a lake would do; hence the lavas when erupted must have been extremely liquid. Some well-preserved craters have been found in recent years.[41]

On the southwest the lava fields have been invaded by block faulting of the Basin Range type; the Warner Range, above described, is there situated; and to the southeast a broad dome has been elevated and dissected, forming the plateau-like Blue Mountains; but over a large area the post-eruptive deformation of the lava sheets has been of moderate measure. A consequence of the broad lava outpourings, taken in conjunction with the less arid climate of the Northwest than that of the Southwest, has been the erosion of normally continuous valleys by the rivers of the region. Of these the Columbia, entering in large volume from the mountains of western Canada, and its main branch, the Snake, heading in Yellowstone Park, are the longest. The continuous valleys of the Northwestern lava-covered country are therefore in strong contrast with the discontinuous valleys of the southwest.

A curious contrast is presented by the exceptional Northeastern and Northwestern regions. The Northeastern was temporarily covered, during a time of climatic chill, by a heavy, stratified, sluggishly mobile cover of whitish crystalline rock, familiarly known as ice, which was supplied by cold precipitation of water vapor from the higher atmosphere, and the ice cover severely scoured the surface over which it slowly crept outward from its Canadian centers of greatest accumulation until it disappeared by melting when the chilled climate warmed again. The Northwestern is more permanently occupied by a heavy, stratified, immobile cover of blackish crystalline rock, commonly known as lava, which was supplied by hot ascension from deep-lying subterranean reservoirs, and the frozen lava cover stands motionless while it is undergoing slow removal by weathering and streaming.

The Call of the Desert

Let no one imagine that the usual shortstopping of the valleys in our Western mountain ranges and, in consequence thereof, the prevailing absence of valleys from our Western intermont plains, to which repeated emphasis has been given in the preceding pages, should be regarded as in any sense physiographic defects. They are simply facts of occurrence or of non-occurrence, and are quite as normal and proper in their actively and irregularly disturbed arid region as valley continuity in the equable and humid East. The facts regarding the valleyless plains are peculiar and deserve to be remarked upon, but the remarks are not to be taken as in the least fault-finding. I would as soon censure the earth for running along its orbit more slowly in July than in January as complain of our basin plains because they are for the most part valleyless. Furthermore, while the desert nature of the greater part of the Southwest has also been insisted upon, it must also be insisted that the desert region is by no means utterly barren and worthless.

[41] W. T. Stearns, "'Craters of the Moon' in Idaho," *Geogr. Journ.* (London), 71: 43–49, 1928. Many features of the lava plains have been admirably described by I. C. Russell in several publications of the U. S. Geological Survey: Fourth Ann. Rept., 1884, 431–464; Bulletins 199, 1902; 217, 1903; 252, 1905; Water-supply Papers, 4, 1897; 78, 1903.

In the first place, the mountains of the desert rise into a cooler and moister climate than that of the plains around their base, and the mountains are coming to be used as summer resorts to a degree that may surprise many an Easterner, who hardly imagines the West to be so far advanced as to take time off for summer vacations. In the second place, many of the mountains have yielded and are still yielding metallic ore of enormous value. In the third place, although the greater part of the desert must remain desert, it contains many irrigated oases which have an attraction, indeed, a charm all their own, and their charm is coming to be more and more recognized by traveling Easterners. This is particularly true in recent years, since the great extension of improved highway construction has made cross-country travel in one's own car so enjoyable, and since due preparation for the reception of visitors has been made in so many of the oases. Even the residents in the desert towns themselves seem now to be less afraid than they used to be of calling the surrounding empty spaces by their proper name of desert, and they would do well to go one step farther and adopt the contrasted name of oasis for the desert towns, because that name has a much more alluring connotation than "settlement."

But it is to the call of the empty and valleyless desert plains themselves that this closing section of my story is to be devoted. In earlier times, when the desert dominated man, it was terrible, but now that man so largely dominates the desert it becomes a region full of entertaining wonders. It supports, except in the stream-swept washes and on the playa flats, a varied, open-spaced vegetation of unusual interest, from the long-lived giant cactus and the fantastic Joshua tree, to the little annuals that hasten to flower after the spring rains. A visit to the dry country in that season is to be warmly recommended, even if the descriptions of the "desert in bloom" are usually overcolored. The unexaggerated facts are good enough, although they are more difficult to set forth in truthful positives than in extravagant superlatives.

To see the facts rightly one must look closely and patiently. Among the flowers to be sought for is a minute, daisy-like composite, which is to my inexpert eyes more remarkable than the showy crimson cactus blossoms. Its stem rises less than an inch from the bare ground; its short roots are tender little fibers; its flower, although perfectly formed, is hardly more than a quarter of an inch in diameter and its seeds must be microscopic; yet, lying on or very close to the surface of the dry soil, they manage to preserve a spark of vitality through the parching heat of a whole summer of torrid Arizona noons to say nothing of the occasional freezes of winter nights, so that when the spring rains come again they germinate, grow up and down and blossom, complete in every little part, and thus pass on the spark of life to another year. If a despairing prisoner ever, as "Picciola" tells, gathered hope from the single flower that sprouted from a crevice in his prison wall, how many million hopes may the traveler on the desert gather from these indomitable little entities which so dutifully perform their life work under conditions apparently so adverse!

To one brought up in the geologically tame and climatically humid East, it is like reincarnation in another world to spend his later years in the geologically wild and climatically arid West. A new set of generalizations has to be made, to do justice to the new and strange environment; and at first it is difficult not to regard the new set as in a certain sense abnormal, because they are so unlike the long-familiar old set. But here the philosophy of relativity supplements the philosophy of evolution and helps

one to see that the new set of generalizations differs from the old no more than the old set differs from the new. It would be a confession of provincial-mindedness to think otherwise. The miniature daisy-like composite of the Western deserts is just as "normal" as the larger daisy of the Eastern pastures. The 15,000 feet of Pliocene strata near Santa Barbara on the Pacific coast, tilted up, overriden by Eocene strata and greatly eroded in Pleistocene time, are just as "normal," although shockingly surprising to an Easterner, as the much less thickness of undeformed Pliocene on the Atlantic coast. The occurrence of discontinuous mountain valleys and of valleyless plains in the West is just as "normal" in their geologically active and climatically arid region as is the prevalence of continuous valleys across mountains and plains alike in the geologically quiescent and climatically humid East. It is the contrast between the two, not the abnormality of either, that deserves emphasis, and I hope that this long story may help to make the contrast better known. But let me confess, in closing, that in spite of the repeated protests I have made here and elsewhere against the misuse of the old term valley as a name for a plain, I have no expectation that San Luis "Valley," Cache "Valley," the Great "Valley" of California or Salt River "Valley" in Arizona will ever be called "plains," as they physiographically should be, by the people who live on them.

LIGHT AND MEDICINES

By Dr. H. V. ARNY

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HAVE you ever received from the druggist a colorless liquid prescription, which, within a week or so, became pink or green or yellow? Have you ever purchased a golden-yellow ointment to find that within a month or so it darkened to a nondescript gray? Have you ever noted that a bottle of perfume, delightful upon opening, became less agreeable and changed color as well as the months rolled around?

All these phenomena are occurring every day, causing annoyance to manufacturers and worry to pharmaceutical dispensers, who have to explain to irate customers why a colorless apomorphine solution turns green within twenty-four hours and why a mixture containing phenol is apt to turn pink.

The manufacturers and the dispenser desire to furnish the consuming public with the best medicaments available. They purchase the choicest materials, they compound them with the utmost skill, they assay the finished product and thus standardize it to a definite strength, and then after all these precautions have been taken they sometimes find to their disgust and to their financial loss that the perfect product they evolve becomes imperfect through no fault of their own; becomes deteriorated (even when bottled in a sterile glass container) by action of some outside factor over which they have no control. These deteriorating factors are of several types. In some cases the action of air produces changes just as the action of moist air is responsible for the rusting of iron. In some cases the type of glass of which the bottle is made may be the mischievous factor. And in many cases the action of daylight is responsible for the change, just as daylight, and especially sunshine, fades the color of the wall-paper of our rooms.

And so we have a considerable list of what we call light-sensitive chemicals and other medicaments, the United States Pharmacopœia and the National Formulary (our two national standard authorities for the quality of drugs and medicines) listing no less than 423 medicaments that should be protected from light. These light changes are mischievous where medicines are involved. On the other hand, there are instances where carefully controlled light changes are beneficent gifts of nature to man. Thus, as aptly said by a former president of the American Chemical Society, a vast industry is based upon a single chemical reaction produced by the action of light, the darkening of silver salts when exposed to light being the foundation of photography and all that photography now implies.

The mischievous effect of light on medicaments is more annoying than serious. It is true that when white crystals of santonin (that vermifuge obtained from Turkistan wormseed) turns yellow, the decomposed product has been known to produce dangerously irritating effects. In most cases, however, the deterioration either lessens the medicinal value of the product or is annoying either from the psychological or esthetic standpoint. A colorless liquid medicine that turns green overnight is apt to alarm a crochety patient. A colorless solution that deposits a dark coating upon the walls of the bottle is not beautiful to behold. Hence both manufacturers and retail pharmacists endeavor to

lessen such light changes in the medicines they produce or dispense. This explains the use of blue or amber glass bottles. This is the reason why careful pharmacists dispense "eye drops" in bottles enclosed in opaque cardboard cartons. This is why the labels on bottles of certain staple chemicals bear the caution, "Store in a dark, cool place."

For fifty years or more pharmaceutical and chemical investigators have been endeavoring to solve the riddle of deterioration of chemicals under influence of light. These researches have been directed (*a*) as to the chemical effects of such deterioration and (*b*) as to means of preventing such deterioration. A mass of literature on these topics is available but, as an eminent Dutch investigator has written the author, this material "was not of value save in this respect—that I learned from it how it had not to be done."

Since the introduction of biological medicaments—sera, vaccines and glandular products—the problem of light changes has become distinctly acute, as these medicaments are very sensitive to light and a deteriorated specimen is sometimes worse than inert; it may even be harmful to the patient.

In a discussion of this topic at the 1926 meeting of the American Pharmaceutical Association it was decided to appoint a committee to study the problem of light-sensitive medicines, and after a two-year preliminary survey, the findings of the survey indicated the need of definite research on the problem. As these findings have been published elsewhere,[1] it only need be stated at this time that inquiry among pharmacists, chemists, physicists and glass manufacturers showed little practical knowledge of the problems, the only worth-while work having been performed by the physicists of the Bureau of Standards and by two foreign investigators, Dr. J. Eisenbrand, of Germany,[2] and Dr. J. B. M. Coebergh, of Holland.[3]

Armed with these facts the present writer, in May, 1928, called a conference which was attended by representatives of the American Pharmaceutical Association, of two associations of pharmaceutical manufacturers and of the association of bottle manufacturers. After discussion lasting throughout the day, it was decided that definite research along practical lines should be carried out, and the present writer was authorized to appoint a committee to raise funds for such a research. This fund-raising campaign was carried out last year and a $2,000-research fellowship was provided for, eighteen subscriptions for $100 each being secured from pharmaceutical and chemical manufacturers, while the remaining $200 necessary to complete the fund was obtained from the Research Fund of the American Pharmaceutical Association.

The $2,000 being secured and turned over to a trustee, the writer secured as his research assistant Mr. Abraham Steinberg, a graduate student of the College of Pharmacy of Columbia University, and these two with the cooperation of Abraham Taub, professor of physics at the same institution, are now engaged in the research which may be outlined as follows.

With the fine cooperation of chemical and pharmaceutical manufacturers and of the manufacturers of glass bottles the necessary chemicals and pharmaceuticals and the appropriate containers have been secured.

The medicinal substances undergoing tests are of such varied character as sweet spirits of niter, bleaching powder and apomorphine, the only point of resemblance being that all are known to be sensitive to light. These samples (thirty-six in number) have been placed

[1] *Jl. Am. Pharm. Assoc.*, 17: 1056, 1928.

[2] *Pharm. Ztg.*, 72: 247 and 1275, 1927.

[3] Inaugural dissertation, 1920.

in pyrex tubes, and these well-corked, wax-sealed tubes are in turn placed in the glass container that is being tested. The pyrex tubes (obtained through the courtesy of the Corning Glass Works) are used as the real container since that type of glass is less apt to affect the chemical stored therein than an ordinary glass bottle. The outer container actually under test is at the present time limited to seven kinds of bottles: (*a*) three types of green, (*b*) one type of blue, (*c*) two types of amber, (*d*) one type of flint, or colorless. The spectrophotometric reading of each of these seven types of glass containers has been recorded, thus fixing the color transmission of the glass in question. It is interesting to note that such spectrophotometric reading of a number of the batches of bottles received from the several manufacturers cooperating in the research shows a distinct uniformity in color of their respective stocks, especially where amber and flint glass are concerned.

We are at present subjecting more than two thousand specimens to the action of sunlight. One set of three hundred specimens is kept indoors on shelves near a window, thus matching conditions found in the average stock room. This set examined month by month in their sealed pyrex tubes will be kept a year before the containers are opened. The remainder of the present batch of specimens (numbering 1,700 items in all) are fastened on panels each protected by a sash of glass, these specimens being exposed on a roof to the effects of unimpeded daylight. One batch of samples is being exposed for one month, and this batch will soon be taken in and examined as to the effect of one month of winter daylight. A corresponding batch of the same chemicals and the same type of containers will be left on the roof for one year, thus subjecting these medicinals to both winter and summer daylight. Those medicaments which our tests show survive exposure for one month will be bottled and exposed two, four and six months respectively. Incidentally, we plan to repeat the one-month experiment during the summer, thus having a comparison between the effect of winter daylight and summer daylight.

Each of the medicaments that we are studying has been examined chemically and physically and has been found to comply with the requirements set forth by the United States Pharmacopœia. The surplus stock (in their original containers) are stored in our dark room and will be examined from time to time in order to detect deterioration due to causes other than exposure to light.

As to batches of medicaments which are brought in after exposure to one, two, four, six and twelve months of daylight, they will again be examined as per tests of the pharmacopœia as to strength, purity and physical appearance. Some of the chemicals exposed show deterioration (color change, etc.) after only a few days of exposure. In other cases the change is more subtle. In ether, for example, decomposition is shown by the appearance of peroxides, and the special chemical test provided by the pharmacopœia will indicate such change to us. In other cases, such as Labarraque's solution, deterioration will be indicated by a loss of strength of the essential component, thus giving an exact measurement of the deterioration month by month.

"What's the use of all this work?" may be the query of the casual reader. In the first place there is apparently no authentic record of the relative value of colored glass containers in preventing the deterioration of chemicals under the influence of light. In a general way we have learned by empiric methods that clear glass bottles are not good containers for light-sensitive chemicals; we

think that amber bottles are the best containers for such chemicals and that blue bottles are the worst, but these opinions are based largely on guess-work. Coebergh, by the use of light rays of known wave-length, found that different chemicals have different sensitivities to different light rays. We are acting upon the Coebergh findings by applying his idea to the medicaments stored in the bottles themselves. By this method we hope to tell manufacturers of pharmaceuticals, of chemicals and of bottles exactly what type of bottle is best suited for the storage of each chemical studied. We hope to give definite opinions as to whether deterioration, wherever observed, is due to the action of light or whether some other factor, such as alkalinity of the glass container or the influence of the air, produces the undesired change. And lastly, we hope, in those cases where light is clearly proved to be the destructive factor, to discover in each case the appropriate "stabilizer," that appropriate chemical a trace of which may aid the medicament in resisting the untoward action of light rays.

THE NEWER HOMEOPATHY

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I

Stone Age physical and chemical science pictures each and every material substance as a crystallized or condensed spirit, or spirit-fragment. The water in the domestic bowl, for example, is a conscious, intelligent, autonomous ghost-concentrate, constantly evaporating or dematerializing into invisible water-potentiality. This intangible potentiality fuses with and becomes an integral part of the great aqueous oversoul, general humidity. Through this atmospheric fusion the captive water broadcasts its pleasures, pains, friendships, enmities and motor impulses to near-by clouds, mists, lakes, rivers and oceans.

Taking advantage of this invisible atmospheric hook-up, Stone Age meteorologists attempt environmental water control. Artificial ripples in the domestic bowl, for example, might logically telegraph sufficient motor impulse to a near-by lake to overturn an enemy canoe. Sprinkled on the ground, the captive water might broadcast sufficient precipitation-impulse to cause general humidity to materialize in the form of rain. Thrown on hot stones, the tortured water sample conceivably radiates man-fear and evaporating impulse, sufficient at times to cause dematerialization of local clouds or mists.

Through a similar atmospheric hook-up with generalized ancestral tribal gas a tortured enemy logically telegraphs cowardice and bodily weakness to his distant tribal brethren. Pierced with thorns, the foot-prints of a lion relay lameness to the jungle cat. Milk, inadvertently spilled on fire, telegraphs intangible fire spirit to bovine udders, sufficient at times to cause cessation of milk flow, or even ulcerative lesions of the mammary glands.

II

Logical and consistent application of the same invisible telegraphy was probably the first system of medicine developed by our prehistoric ancestors. A fragment of snake skin, tortured by smoke, pulverized, swallowed, subsequently insulted by gastric juice and finally cast off from the human body, would logically broadcast man-fear, snake-cowardice and snake-attenuation to near-by serpents. Thus inductively cowed and weakened, local snakes would rarely bite man. Their telepathically attenuated venom would do little or no harm. A sample of a patient's ghost-consubstantiated blood, narcotized with plant juice, inductively narcotizes the invading consubstantiating ghost. Swallowed by the patient, the narcotized hemic ghost-fragment cries out in terror to the residual pathogenicity, initiating its deconsubstantiation. Tubercular sputum mixed with dry earth, then applied as cutaneous massage, telegraphs dryness and perspiration-attenuation to invading phthisis, primitive perspiration being an external gastric juice more powerful than any digestive ferment of modern science.

If a fragment of the invading pathogenicity can not be obtained for ceremonious torture, equally logical induction therapy is possible through imitation, or double-relay magic. An image of a tiger is constantly evaporating into invisible synthetic semi-tiger potentiality, which mingles with and

partially fuses with the real atmospheric tiger spirit. Ceremonious torture of the image, therefore, is relayed to the great tiger oversoul and, through this oversoul, transmitted to the jungle enemy. By the same logic, an image of an invading pathogenic ghost, narcotized, insulted, mutilated and swallowed, relays terror and attenuation to the real pathogenicity. A ceremoniously tortured smallpox image inductively terrorizes environmental smallpox. Or, clothed in rich robes, praised, flattered, fed with sacrificial meats, it relays pseudo-friendship to the environmental virus, sufficient at times to change this invisible anthropophagus into a loyal servant of the local tribe.

III

With the development of later social organizations Stone Age therapeutic magic was changed to a real homeopathy. With the union of families into clans, tribes and nations, similar group organizations were conceived to take place in the pathogenic world. Each virus-group was usually dominated by some particularly virulent organ-eating or symptom-producing ghost. It was no longer necessary to procure a sample or to prepare an image of an individual virus. Any member of the symptom-specific group could be captured or imitated. Through ceremonious torture of this group representative, attenuation and terror could be relayed. A real inductive *similia similibus curantur*. Baldness, for example, could be inductively weakened or scared away by a swallowed gastro-intestinally insulted fragment of frog skin, an easily attainable consubstantiated anti-hairiness potentiality. Excreta from any form of diarrhea could be tortured and applied as cutaneous massage, relaying through the bellyophagic clan-organization attenuation and man-fear to invading gallstones, appendicitis, cholera, typhoid fever and other abdominal pains.

This early pagan *similia similibus curantur* did not reach its *reductio ad absurdum* till all pathogenicities were enrolled under the captaincy of the medieval unitarian Satan. Formal burning of a Satan-consubstantiated witch, the eating of roast or fire-attenuated witch flesh and the torture of an imitation Satan in the bull ring thus became the major official method of disease control.

IV

With the development of nineteenth century Christianity, however, not only did this unitarian antisatanotherapy become obsolete, but all earlier forms of therapeutic magic became equally illogical. Autonomous or group-motivated spirits were no longer conceived to control pathogenic viruses.

In spite of this theological discard, however, the essential technique of early pagan *similia similibus curantur* was retained and justified by new hypotheses drawn from material science. Our Stone Age ancestors postulated that, in addition to magically induced cowardice and attenuation in an invading pathogenicity, the swallowed or cutaneously applied, ceremoniously attenuated virus-sample systematically exercises and increases the consubstantiation-resistance of the human body. Swallowed snake skin, for example, was a logical Stone Age vaccine, whose easy conquest and expulsion from the body strengthens and encourages the normal human anti-snake potentiality. Fecal massage is a Stone Age cutaneous vaccine, systematically training the human gut for war against visible and invisible fecophilic viruses.

This retention and metamorphosis of theologically discredited pagan homeopathic magic into a modern physiological science is usually attributed to Hahnemann. The Hahnemann physiological theory assumed that, given in small, readily conquered doses, any

symptom-producing material is a symptom-specific vaccine, training and increasing physiological symptom-specific resistance. A headache-producing drug is a postulated logical therapeutic vaccine against all forms of headaches. Morphine logically immunizes against insomnia. Alcohol trains and strengthens locomotor-ataxia-resistance.

V

The Hahnemann renaissance of early pagan homeopathic technique under this new rational was, of course, not without its critics. Nineteenth century medicine had become so skeptical of metaphysical deductions as to demand convincing experimental and clinical proof. Very suggestive evidence was soon quoted by Hahnemann—the therapeutic vaccine, nitroglycerine. Given in toxic doses nitroglyycerine produces a most excruciating headache. According to Hahnemann immunology, therefore, oral administration of minute, easily licked doses of nitroglycerine should increase headache-resistance. Hahnemann pointed with pride to the fact that patients suffering from headache are at times almost miraculously cured by such administration.

This observation was probably the most important single research stimulus of the nineteenth century. At the time it was made, biologists knew nothing of the physiological action of nitroglycerine, and only the most fragmentary physiology of any currently used empirical remedy. Pro-Hahnemann and Anti-Hahnemann controversies, therefore, were pure metaphysics. It was not till the closing decades of the nineteenth century that physiology was prepared to present scientific evidence.

By this time impartial non-clinical research had shown that nitroglycerine belongs to a relatively large group of toxic agents, producing as its most easily demonstrated physiological effect a lowering of arterial blood pressure. Clinicians had long noted that there are different types of headache—one type, for example, associated with abnormally high blood pressure, a second type characterized by subnormal arterial pressure. Impartial clinical tests now showed that nitroglycerine given to a patient with high-blood-pressure headache at times restored blood pressure to normal, often accompanied by cessation of painful symptoms. Given to a low-blood-pressure headache, however, nitroglycerine was found to further decrease blood pressure, invariably magnifying the distressing symptoms. Nitroglycerine, therefore, was not the symptom-specific vaccine Hahnemann assumed. Moreover, there was no evidence that this toxic substance had any immunizing power whatsoever. Given in repeated minute doses to laboratory animals nitroglycerine stimulated the development of no increased resistance or supertolerance even to nitroglycerine itself.

Similar impartial laboratory and clinical studies failed to demonstrate the postulated immunizing powers for such common drugs as quinine, iron, mercury, strychnine, caffeine, digitalis and pilocarpine. Fully 98 per cent. of nineteenth century empirical pharmacology was thus shown to be in non-conformity with Hahnemann immunology. Hahnemannism at most could be but 2 per cent. clinically true.

VI

A few of the less common therapeutic agents of mid-Victorian empiricism, however, and many agents subsequently introduced were found to stimulate the development of a remarkable tolerance, sufficient at times to protect man or laboratory animals against many hundred times the usual lethal dose of a toxic agent. Among the commoner agents thus found in apparent conformity with Hahnemann immunology are

numerous zootoxines (*e.g.*, snake-venom), numerous plant extractives (*e.g.*, mushroom poison), and almost any toxic or non-toxic substances of microbic origin. Scientific homeopathy, therefore, was forced to turn its sole attention to these few apparent confirmations of the Hahnemann postulates.

These apparent confirmations of Hahnemann immunology, however, were soon found not to confirm his major belief. Immunization with subtoxic doses of cobra venom, for example, while demonstrably increasing cobra-resistance, was found to give little or no increased protection against other zootoxins, and no protection whatsoever against other toxic agents producing the same or similar symptoms. With very rare exceptions the immunity following vaccination with any morbidic agent was demonstrated to be highly specific for that agent.

VII

Furthermore, even the few successful specific immunizations were soon shown to be effected by a physiological mechanism not dreamed of by symptom-specific immunology. Normal laboratory animals, for example, injected with moderate doses of cobra venom, usually die as a result of cardiac paralysis. An excised normal animal heart, kept alive under artificial circulation, usually ceases to beat from two or ten minutes after a milligram of cobra venom is added to the circulating fluid. The heart of a cobra-immune animal is equally susceptible. Cobra immunity, therefore, can not be explained on Hahnemann assumption of increased organ or symptom resistance.

Still further limitations of Hahnemann homeopathy were soon found necessary, proof of error in the postulated belief that minuteness of dose favors immunization. The exact opposite was at times demonstrated to be true. Injection with too small a dose of a successful immunizing agent occasionally leads to the development of the exact opposite of an acquired immunity, causing an acquired hypersusceptibility. Vaccination of certain laboratory animals with too small a dose of egg-white, for example, may stimulate the development of a specific idiosyncrasy to egg albumen. Subsequent feeding or injection with egg-white may throw the specifically hypersensitive animal into fatal convulsions, or lethal shock. The newer scientific immunology, therefore, was forced to limit itself to the relatively few immunizing agents with which immunization is possible without risk of stimulating the development of the distressing and often dangerous opposite effect.

VIII

Thus limited, stripped of every vestige of its original *similia similibus curantur,* giver a new nomenclature and an entirely new physiology, the ½ per cent. residual fragment of Hahnemann homeopathy is to-day endorsed by and is an integral part of scientific medicine.

The evolution of this newer circumscribed scientific homeopathy epitomized medical history. Conceived by Stone Age wizards as a logical magic against individual pathogenic ghosts, raised to a theological *similia similibus curantur* by later paganisms, discarded as pagan superstition by modern Christianity, its essential technique rescued from this discard by nineteenth century adolescent material science, robbed of 99½ per cent. of its assumed physiological rational by later experimental and clinical research, its residual ½ per cent. verifiable biological truth is to-day officially endorsed by conservative clinical science.

The next step, of course, will be a modification of existing legislation in conformity with this evolution.

THE PHYSICAL NAPOLEON

By Dr. JAMES FREDERICK ROGERS

THE U. S. OFFICE OF EDUCATION

The rise or the fall of a great man, aside from the combination of external circumstances which may make or destroy him, is largely influenced by his physical condition. Of no man is this more evident than of Napoleon, whose physical powers were as marvelous as his mental accomplishment, and the waxing and waning of whose star, while far from being wholly determined by, was significantly coincident with, his bodily development and decline.

Napoleon's father, who is described as slight, lithe and handsome in face and figure, and full of energy, died at the age of thirty-nine of cancer of the stomach. It was from his mother, however, that the illustrious son seems to have derived his unparalleled physical powers. She is said to have been a remarkably forceful and courageous woman, of heroic mold and of great beauty, which she retained to advanced age. She shared with her husband the hardships and perils of the Corsican struggle against the French, and it was while she was following the fortunes of Paoli's patriots in one of their expeditions that Napoleon was born.

As a child Napoleon was "turbulent, active and lively in the extreme," and in such an atmosphere of national strife it was but natural that his favorite playthings should be a sword, drum and toy soldiers. He was sent to school at six, and on his way he is said, by tradition, to have regularly exchanged his own piece of white bread with a soldier on duty for a bit of the coarse army loaf. He was teased at school for his devotion to one of the little girls and for walking up and down absorbed in thought, with his stockings falling over his heels. He made furious return for such treatment. He feared no one, and no numbers. He said of himself later, "I struck one, I scratched another, and I was a terror to everybody."

At school in Brienne at the age of ten he held himself aloof from the other boys. He played little and took long walks alone. The pupils were lodged with Spartan plainness in dormitory rooms six feet square. They were served amply with four meals a day—breakfast and luncheon of bread, water and fruit; dinner of soup, meat, a side dish and dessert, and for supper a joint with salad or dessert. With the latter meal a weak mixture of wine and water, known in sarcastic school phrase as "abundance," was served.

Each boy was assigned a small garden plot to cultivate. Napoleon fenced his about with a hedge, fiercely drove out all intruders and spent his leisure here in reading all the books he could find. Though for a long time at odds with his school fellows, his fearlessness of them and his indifference to punishment meted out to him by his teachers won their esteem. They ceased to tease the Corsican, and he, in turn, grew more friendly and entered more frequently into their sports. On one occasion he marshaled his fellows in a mimic war with snowballs and is said to have planned and directed with remarkable skill the building of elaborate snow forts. Among other accomplishments, dancing was taught, and on one occasion Napoleon was one of seventeen who rendered a country dance at a public exhibition. At the age of fourteen he was described in the official report as being of good constitution and in excellent health.

In the next year he was sent to the fine military school in Paris, where, he says, "we were fed and served splendidly." There were also severe discipline and hard work. Lessons lasted two hours for each subject, and there were four subjects each day, except on Thursday and Sunday. The students had military drill every day and on Thursdays and Sundays were taught firing. There were excellent teachers of fencing, dancing and riding, but Napoleon excelled in none of these accomplishments, and, in fact, slighted them, preferring to spend all available time over his books.

At sixteen he was removed from Paris to the artillery regiment of La Fère, one of the best in the army, where, under splendid discipline, three days a week were devoted to theory and three to artillery practice. He took private lessons in dancing and deportment which he had neglected at the Paris school, but he failed to acquire an easy or polished manner.

Although his routine work was arduous, he added to it by his studies and often labored from twelve to fifteen hours a day. At eighteen he contracted a fever, probably malarial, which affected his health to some extent and served as an excuse for furloughs to Corsica. His complaints of ill health continued, and at twenty-three he is described as small, thin and looking spectral and uncanny, with pallid cheeks and dark rings about his eyes.

Two years later at the siege of Toulon he was still remarkable for his extreme thinness and the almost yellow tint of his visage. He was, however, abounding in energy, as evidenced by his work and his "two eyes, sparkling with keenness and will power." He won high praise by his tireless activity and his exhibition of "much science, as much intelligence, and too much bravery." At Toulon Napoleon contracted a troublesome skin disease, probably the "itch," which, from neglect, remained with him until he became consul, and it did not add to the attractiveness of his person. Only the flash of his eyes, those wonderful eyes, gave indication of the tremendous physical energy stored within that slender body.

In 1797, at the age of twenty-eight and in command of the revolutionary armies, he was still very thin, "of sickly hue" and "covered with tetter," but Talleyrand saw in him a "charming figure . . . with a pale complexion, and a certain tired look." The look of fatigue was deceiving, for he was capable of vehement and tireless activity, quite equal to his imagination which was already soaring toward oriental conquest and world empire.

On his return from Egypt he was "very meagre and very yellow, his complexion coppery, his eyes sunken, his shape perfect, though rather slender. . . . His eyes were a beautiful blue, which depicted in an incredible manner the different emotions which agitated him . . . his teeth without being very regular were very white and very good and there was perfect regularity and beauty in all his features. He was five feet six inches in height . . . his neck was rather short and his chest large."

He was, as he said, made for work, and with the colossal enterprises he now conceived and their successful working out he expanded bodily. By the end of the consulate, in 1804, at the age of thirty-five his figure had rounded to a fulness which indicated both mental satisfaction and abounding health and vigor of body. It is in this period that Napoleon's activities reached their climax, and there was a coincident culmination of his physical perfection. Such power for work has never been possessed by any man of whom we have knowledge. "I am conscious," he said, "of no limit to the work I can get through." For both mental and physi-

cal exertion he seems to have been at this time incapable of fatigue. "It would require constitutions of iron," wrote one of his ministers in 1803, "to go through what we do. After a day's ride in a carriage we no sooner alight than we mount on horseback and sometimes remain in our saddles for ten or twelve hours successively." In one battle he went for five consecutive days without sleep and without removing his boots, and he was fully recovered after a sleep of thirty-six hours. In dictating to his secretaries he would walk to and fro for as much as six hours without apparently being conscious of his pedestrianism. He exhausted all his subordinates. His councils of state often lasted eight or ten hours at a stretch. Once at two in the morning when the ministers were all worn out and one had even succumbed to sleep, Napoleon stirred them to further deliberation: "Come, gentlemen," he said to them, "Pull yourselves together, it is only two o'clock . . . we must earn the money the nation gives us." "He could work for eighteen hours at a stretch at one subject or many." "Never," says Roederer, "have I seen his mind weary; never have I seen his mind without spring; not in strain of body, or wrath, or the most violent exercise." Even his enemies declared that his capacity for work was beyond compare and equal at least to four men in one.

While he slept from six to eight hours in the twenty-four, when aroused at any moment of his slumber he was in perfect possession of his mental powers, and could sleep again at will. If compelled to go long periods without sleep, he always made up for the loss. After times of great fatigue "he condemned himself to twenty-four hours of absolute rest," and on one occasion he slept for thirty-six hours.

When at home he arose at about seven. He spent much time over his toilet, for he was exceedingly careful of the cleanliness of his person. He was very careful of his teeth, which he kept in beautiful condition. He had brought from the East the habit of having himself massaged, and the more vigorously he was rubbed the better he liked it. "Harder!" he would say to his valet, "harder! as though you were rubbing an ass!" His bath was completed with a sprinkling of Cologne water of which he was very fond.

He gave very little thought to his eating. He ate very hurriedly, spending only from seven to a dozen minutes at the table. He preferred plain dishes and was especially fond of fricasseed chicken. Red mullet, roast mutton, beans, lentils and macaroni with Parmesan cheese were also favorite dishes. Of roast meats he ate the "brownest" part and had a horror of meat underdone. He rarely drank anything but a half bottle of Chambertin wine at meals, diluted with water. After breakfast and dinner he took one cup of strong coffee. Besides his three meals he often had chocolate or ices, of which he was very fond, served in the midst of his work. He never complained of what was set before him, and sometimes in his abstraction he was not aware that he had dined. His digestive organs occasionally rebelled against his hasty eating, and, recognizing that they knew what they were about, he, by way of cure, ceased eating, drank copiously of barley water and took vigorous exercise, riding horseback at high speed for twenty or thirty miles.

The notion that Napoleon was subject on a few occasions to epileptic fits seems to have arisen from the secrecy maintained by his suite over sudden and prostrating attacks of indigestion.

He found his chief pleasure in work, but "air and exercise were necessary to his existence, and the privation of them, from rain or any other cause, made him

not only disagreeable but really ill." He entered into sports with boyish glee. The favorite game of his suite during the happy days of the consulate was prisoner's base. Napoleon was not very agile, and in running often fell down, but he picked himself up again with shouts of laughter.

He used a great deal of snuff, but only by bringing it to his nose, smelling it and letting it fall from his fingers. "Smoking," in his opinion, "was good for nothing but to entertain idlers."

His senses were exceedingly keen; the slightest bad odor was sufficient to upset him greatly; the smell of paint made him sick. He was fond of the perfume of aloe wood and used cologne constantly, but some perfumes were intolerable to him. He was very sensitive to cold; he often had a fire on the hearth in July, and, except in the hottest weather, he had his bed warmed. He had a horror of impure air, and he turned pale at the remembrance of blood covering his hand from a wound on a friend. When with the army, all this keen sensibility was suppressed and he could stand more of the painful and disagreeable than any common soldier. In the field he went to sleep at seven and began his tireless labors again at one in the morning.

He was always more or less nervous and irritable; he often bit his nails, and he had the habit, when absorbed in thought, of shrugging his right shoulder and at the same time moving his mouth from left to right.

While his enormous energy spent itself chiefly in work, it sometimes burst forth with volcanic fury; in one of these explosions he kicked over the table and smashed the china, and on another occasion he planted his foot with tremendous force against the abdomen of Senator Volney, much to that gentleman's discomfort. His pulse was slow, between fifty and fifty-five, and even in his fits of rage he seems to have been self-contained, as he never felt his heart beating and his valet noted that the blood never rushed to his face.

As emperor, Napoleon grew heavier in body, and his appearance was praised or ridiculed according to the attitude of the witness. Queen Louise admired his head as "that of a 'Caesar,'" but her lady in waiting, who was more sincere, said he was "excessively ugly, with a fat, swollen, sallow face; he was short, very corpulent and entirely without figure." He was becoming obese, but was otherwise the picture of health and strength. The keen, melancholy, fathomless eyes were as marvelously expressive as ever, and his voice was, even to his valet, "of such beautiful quality that, however softly he speaks, it goes to the very depths of the heart."

In 1807, in his thirty-eighth year, Napoleon wrote to his brother that his health was never so good. Percy, one of his surgeons, writing in this year said, "The Emperor is made of iron, soul and body, always on horseback, galloping about in all weathers, bivouacking, working like ten men, never ill, never tired." In September, 1809, Napoleon again speaks of his health as perfect in a letter to Josephine, and in this year he was capable of riding ninety miles on horseback, without stirrups, in five and a half hours, but in two later letters in that year he mentions being ill. In 1810 he speaks in his letters to her of his health as only "fairly good" or "pretty good." There was, from this time, a slow decline of his health and vitality, and with this, of his power for uninterrupted work.

There was no particular ailment which depressed him, but doubtless his growing obesity, against which his physician, Corvisart, had warned him, was at the bottom of it all, for it was by no means a sign of health. This condition indicated that he was eating more or taking

less exercise or both. Surrounded with every luxury, the emperor was not so ascetic as the first consul. He partook of pastries and fancy dishes as well as of plain foods, though it can not be said that he acted the epicure except, perhaps, on one or two occasions when he seems to have been at a loss for other means of passing his time. Judged by the standard of the times he was still temperate in both meats and drinks, though the standard was not the best.

He had some minor ailments, hemorrhoids and possibly bladder trouble, and for these he spent more and more time in hot baths. Neither the complaints nor their treatment conduced to bodily activity or to loss of fat.

His mind seemed about as active and tireless as ever. His ambition and imagination, in fact, outstripped all possibilities, and the failure of the Russian campaign was due more to attempting the impossible than to any physical lapse, though some critics find him wanting in old-time vigor and care for details. His way was certainly not so clear or so easy as in earlier campaigns, and he hesitated and sat idle where previously he had acted.

He had, at this time, become slow in all his movements. There was no sparkle in his eye and his expression was dull. "His lassitude was noticeable and when he roused himself it was often for trivialities." Nevertheless, this was merely a lapse from *Napoleonic,* and not ordinary powers, and on the retreat from Moscow "he shared for days the common hardships of his soldiers, and even marched for hours through snow and mud without showing signs of physical or nervous exhaustion."

In the Dresden campaign of the following year the signs of weakness were more marked. He favored his health, postponed operations on account of rain and "seemed beset with alternate lassitude and energy." At Düben he could not make up his mind, and sat for two days on a sofa with dispatches accumulating before him, engaged in drawing capital letters on sheets of paper. How far mental and emotional factors, not having to do with immediate events, distracted him at this time can never be sifted from the effects of purely physical condition.

Sir Neil Campbell, the English ambassador, said of him, during his imprisonment in Elba, "I have never seen a man with so much activity and restless perseverance: he appears to take pleasure in perpetual movement, and in seeing those who accompany him sink under fatigue." Nevertheless "he occasionally falls into a state of inactivity never known before, and sometimes reposes in his bedroom of late for several hours a day; takes exercise in a carriage and not on horseback. . . . During his ten months at Elba he became very stout and his cheeks puffy." Mollien, one of his cabinet ministers, noticed that at Elba "a kind of lassitude, never known before, took hold of him, after some hours of work."

The Waterloo campaign, the critics tell us, was planned with consummate brilliancy. On June 12 Napoleon rode in his landau seventy miles and "on the next day he got through an immense amount of work." On the fifteenth he was in the saddle for nearly eighteen hours, except for one short period of rest when he fell asleep. That night "he was overcome by fatigue" and the next day was still very weary and did not exert himself until two-thirty, when he rode through a time of terrible heat until night. On the morrow he again showed fatigue. Whatever conflicting mental and emotional states may have had to do with it, the physical Napoleon of Waterloo was not the physical Napoleon of Austerlitz. Nevertheless, he was still Napoleon, and Waterloo, despite the mistakes he may have made, came

well-nigh being a victory for the French, and had it been so, his exhibition of unusual fatigue would hardly have been recorded.

After the battle the defeated man was prostrated, body and soul. His resourcefulness, physical and mental, was for the moment in abeyance. The failure of his achievement to keep pace with his flights of imagination was more than he could bear, and he was aware that his opportunity to recover his place in the world was past.

As prisoner of the English, at the age of forty-six, he appeared to Captain Maitland a "remarkably strong, well-built man, about five feet seven inches high [five and a half inches, according to Constant], his limbs particularly well-formed, with a fine ankle and a very small foot. . . . His hands also were very small, and had the plumpness of a woman's, rather than the robustness of a man's. His eyes were light grey, his teeth good, and when he smiled the expression of his countenance was highly pleasing; when under the influence of disappointment, however, it assumed a dark, gloomy cast. His hair was of a dark brown, nearly approaching black, and there was not a grey hair among it. From his having become corpulent, he had lost much of his personal activity, and if we are to credit those who attended him, a very considerable portion of his mental energy was also gone."

On shipboard his health was, to observation, excellent, despite a heavy consumption of meat. At St. Helena, compared with other men, he was still the embodiment of vigor, and, to quote Lord Rosebery: "One is irresistibly reminded of a caged animal, walking restlessly up and down his confined den and watching the outside world with the fierce despair of his wild eye." During the first four years of his confinement he "practically passed all his days in his hut, reading, writing, talking . . . withal bored to death." The chief event for him was the arrival of books; he would "shut himself up with them for days together—bathing in them, revelling in them, feasting on them." Often he read for ten or twelve hours at a stretch. When he was not reading, his restless energy found vent in dictating his memoirs, and he dictated with a vengeance." On one occasion he kept the pens of his secretaries flying for fourteen hours, only pausing long enough to read what had been written. He sometimes dictated all night.

He would not stir abroad because he hated to be reminded of his imprisonment, his health suffered from lack of exercise and he was troubled much with scurvy, indigestion and headaches. He constructed a sort of exerciser of two beams of wood which worked like a see-saw, but this did not make up for lack of out-of-door life.

In his conversations with his physicians he showed his characteristic acute insight into the medical practice of the day. The use of physic he believed largely irrational, and he considered indiscriminate bleeding, the chief remedy of the time, the waste of so much life fluid. He praised the work of the surgeons as being founded on definite principles. He said he had himself as emperor studied anatomy for a time, but the sight of the specimens (Meneval says they were wax models) was too much for his delicate sensibilities and he gave it up. Though he always had a physician in his employ, he usually relied on the efficiency of his own simple remedies—fasting, drinking abundant water, exercise and hot baths.

"With his restless energy thrown back on himself, he was devoured by his introverted activities. He took the morbid satisfaction of a martyr in the ailments brought on partly by his confinement, and more by his rebellion against it, but finally in his last year, relinquishing the

dreams of a return to former glory, he ceased his self-commiseration and determined to live again. He rode horseback, but his main interest was in his garden." Conspicuous in red slippers and vast straw hat, and surrounded by his valets, stablemen and a gang of Chinese laborers, "he would plan and swelter and dig; for to dig he was not ashamed." He gardened as he had done everything else, on a Napoleonic scale and with Napoleonic impetuosity. The fearful Governor Lowe wrote on December 1, 1819, "Nothing can exceed the bustle and the activity which has been recently displayed by General Bonaparte, in giving directions about his flower garden, and superintending the workmen employed at it. He is hemming it in all around with as bushy trees and shrubs as he can get transplanted, and with sod walls so as to screen himself so far as possible from external observation." Individual as well as general history repeats itself, and Napoleon was shielding himself from the public gaze as he had done from his fellow students in his youthful years at Brienne.

His health had been declining gradually, but it was not until late in 1820, at the age of fifty-one, that the symptoms of his fatal malady became prominent, and it was only in April, 1821, that the seriousness of the ailment was realized by his physicians. He died on May 5 of cancer of the stomach, having retained extraordinary vigor to the last. At the postmortem examination all the organs, except the stomach, appeared sound, and his body, "far from showing the emaciation that usually results from prolonged inability to take food, was remarkably stout."

The physical Napoleon is not a striking figure in size, symmetry or in display of muscular prowess. What impresses us is his astonishing vigor and endurance. It was through these that he was Napoleon. Such a possession comes through heredity and not by training. Given such an inheritance, however, it requires some care to bring it to maturity, and it is significant that in his earlier years he set for himself a high standard of temperate living.

It is to be noted that Napoleon's phenomenal powers of endurance were not developed on the athletic field. Though he had the routine work of the military school he slighted some of his opportunities for physical activity, and, though football and tennis were favorite sports, we are not told that he figured in either. Such an insignificant-looking youngster would be an unlikely candidate for any "team" in our modern colleges. His play was chiefly mental, and his apparatus, books; but he stored enormous reserve of nervous energy. In this respect he resembles such other mental athletes as Michelangelo and Titian, Johnson and Scott, Beethoven and Brahms.

His capacious nervous system was backed by a vegetative machinery which was perfect. He took fastidious care of his body in many ways, and doubtless had he realized the possible effects of his obesity he would have attempted to correct that condition. He was not accused of intemperance in eating even by his enemies, and until he became emperor he certainly did not eat for pleasure but that he might get the eating done and be at work. He hated the abuse of alcohol and never in his darkest moments resorted to the use of narcotics. He considered smoking a waste of time.

Even as emperor, while he allowed his ailments and growing sensitiveness to discomfort to have some ascendancy over his former simplicity of living, he was, as compared with other men, in comparative vigor and health to the last.

The bodily unfolding of Napoleon kept pace with the successful working out of his ambitions and declined apace when the two could no longer keep company. Nothing is so conducive to health as ab-

sorbing and satisfying work, and no man ever had vaster dreams or realized them more fully up to the time of the empire. Thereafter he dreamed, but his visions were more than even he could work out, and he became confused in the maze he had created for himself. He was thrown back upon himself with disastrous friction in his nervous machinery.

The effect of all this culminated at Waterloo. The corpulent figure with head sunk between his shoulders, prevented from falling from his horse by trusty hands on either side, was but partially that of a man in diminished health or extreme fatigue. It was more that of a man for whose still phenomenal energies there was, so far as he could see, no outlet. Emotions will depress more than work, and the sight of his shattered army was too much for the man who, ten years earlier, knew no such thing as exhaustion of bodily or mental resources.

There were moral factors also that must have affected his physical nature. He is said to have come to hate war, and we know that he mourned over the loss of some of his generals. The divorce of Josephine was a severe wrench. He must have felt the emptiness of his "success," and not even his fancy could smother the fact of the instability of the position he had reached. It is little wonder that he became more and more irritable and was to his marshals a "very devil of a man."

There has been much discussion and disagreement among the critics of the battle of Waterloo as to whether the result was influenced by Napoleon's bodily ailments. A battle is a complicated piece of business, and Waterloo was no exception.

"In your profession, if you were once to fall ill, you would be a ruined man." Thus did the father of Michelangelo warn his son; but if illness could so affect the fortunes of an artist, how much more serious the slightest fall below par must have influenced the career of Napoleon on that fatal field.

More has been written about Napoleon than about any other man of modern times, and for the reason that he always remains a mystery. His physical career, being bound up with the rest, partakes of that mystery. Was the clockwork of his bodily machinery set by heredity for an early decline of his unheard-of perfection? Did that powerful machine burn itself out from very intensity of activity? Was there a decline due to a forgetfulness of the asceticism of his earlier days and negligence of certain physiological laws, and can soft living, corpulence and some trifling derangements be blamed for the falling of his star? Did pangs of conscience cause a disastrous grinding of his nervous machinery upon itself, or was it simply that the balance of political conditions in France and in Europe had finally fallen beyond his control? Probably all these factors combined to shorten the meteoric career of this man of whom Lord Rosebery wrote: "Till he had lived no one could realize that there could be . . . such prodigious vitality of mind and body."

THE WORLD AND THE BUTTERFLY

By AUSTIN H. CLARK

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TRUE appreciation of any form of animal life is quite impossible unless we constantly bear in mind the intricate and varied contacts of that form of life with other forms of life, both animal and vegetable, and also with the inanimate or inorganic world.

In order to understand and to appreciate the intricate nature of the complex, both living and non-living, that enmeshes every type of animal life, holding it rigidly to its proper and appointed place in the cosmic plan, we may consider the numerous and varied contacts of a butterfly.

Did you ever realize that for their existence butterflies depend upon the sea? The young of butterflies are known to us as caterpillars. Caterpillars eat leaves—or at least the great majority eat leaves. Leaves are produced by plants. In order to grow, plants must have water. Water comes to them in the form of rain. Rain is moisture condensed from the air passing in the form of winds above the earth. Most of this moisture gets into the air through evaporation from the surface of the seas which cover seven tenths of the area of the world.

So there really is a close connection between the butterflies and the ocean. This connection is made up of many links which involve almost every line of science.

For instance, astronomy plays a part. The emanations from the sun provide the energy by means of which the water is evaporated from the surface of the sea, which causes the winds to blow, and which, acting on the green substance in the leaves of plants, enables them to form organic out of inorganic substances.

In other words, the emanations from the sun make possible the physical processes and chemical reactions on which the existence of the butterflies depends. And besides this, the element of time, so far as it affects life, is an astronomical phenomenon dependent upon the spinning of the earth upon its axis and on its course about the sun.

Weather and climate play an important part in directly affecting the lives of all the butterflies. They also affect them indirectly through their action on the sea, in some cases thousands of miles away. As an example, the alpine butterflies on the mountain tops in south central Asia depend on snow and rain which is brought to that region in the form of water vapor by the higher currents of the air from the Atlantic Ocean across the plains of Europe and of western Asia.

Soils are formed from the disintegration of the rocks. Rocks are continually breaking up and being washed away as mud or sand or gravel. In this way is formed the basic food of the plants which support the butterflies.

Besides this, the muds and sands and gravels deposited in water are continually being reformed and consolidated into the so-called sedimentary rocks. Once in a while a butterfly gets stuck in mud and covered up. This mud may later turn to rock. When this happens we have a record of the sort of butterflies that existed at the time when that rock was mud. It is quite unusual to find butterflies as fossils in the rocks, though a fair number have been found and studied.

These fossil butterflies all belong to that far-distant period known as the Miocene and lived many millions of

years ago. In spite of their very great antiquity they differ very little from the kinds we know to-day. Most of their living representatives, however, are found in different regions. Thus in Colorado we find a type now confined to Africa, and in Germany we find other types which to-day live only in America.

Most caterpillars are able to subsist only on a very limited number of different kinds of plants which are closely related to each other in their chemical composition. The cabbage butterfly feeds only on cabbages and a few closely related plants and on nasturtiums.

Some enormous groups of butterflies feed only on a single type of plant, as the so-called *Aristolochia* swallowtails which feed only on *Aristolochias,* and also our fritillaries, which feed almost exclusively on violets. Very many kinds of butterflies feed only on a single kind of plant, like our beaked butterfly and tawny emperor which as caterpillars are found only on hackberry trees. But a few kinds of butterflies, like our common yellow swallowtail, feed on a very great variety of different and unrelated plants.

From this it becomes evident that female butterflies must be expert botanists, for they must be able accurately to identify those plants which are suitable for use as food by the caterpillars of the coming generation. Or perhaps it should be said that they must be expert chemists, for they not infrequently will pick out a plant chemically suitable as food, but botanically widely different from any other plant which they or their ancestors—at least for thousands of generations—could be supposed to know.

As an illustration, the female of the common cabbage butterfly will freely lay her eggs on garden nasturtiums (*Tropaeolum*) which belong to a family of plants (Tropaeolaceae) confined to Central and South America and not at all like any of the plants of the cabbage family (Brassicaceæ) upon which ordinarily this Old World insect feeds.

Butterflies have very many enemies of every conceivable description. The Australian natives are very fond of certain kinds of butterflies, and grow fat on them if they can get them in sufficient quantities. In Central and South America and especially in Africa the caterpillars of several kinds of butterflies used to be—and in some places still are—in much demand for food.

Certain bats are very fond of butterflies, and mice and shrews eagerly devour them. Some birds feed partly, and in the tropics largely, on them. Certain small lizards and some of the smaller snakes are very fond of them. Among their insect enemies are mantises, various predacious bugs, robber-flies, dragonflies, hornets, ants and the so-called caterpillar wasps.

But their worst and most destructive enemies are various sorts of small wasp-like flies which lay their eggs upon or in their eggs, their caterpillars or their chrysalids. The small maggots which hatch from the minute eggs of these parasites feed upon the contents of the egg of the butterfly or upon the juices of the caterpillar or upon the contents of the chrysalids. Some of the true flies which in their appearance are much like little blue-bottles also have this parasitic habit. And besides these enemies butterflies have many more, for instance, nematode worms, gordian worms, bacteria and protozoans, spiders and mites and sometimes even mosquitoes.

Such in brief are the more important contacts of a butterfly. In considering the living world it is important constantly to bear in mind that every sort of animal, no matter what it is, has just as many and just as varied contacts as has a butterfly.

SPECIALIZED EDUCATION AND ITS VICES

By Dr. D. B. KEYES

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We have been told by writers all over the world that this is the age of specialization. Success comes to those who know considerable about one small, narrow field and little or nothing about many fields. This doctrine has been preached in the universities of the country. Even our science students have been led to believe that success in applied science depends on rigid specialization. Young men who intend to go into research and development work in industries, especially work involving physics and chemistry, have often been told that they must become experts in some narrow field of physics or chemistry before they can possibly hope for success.

The actual experience of our graduate students in industry has been quite to the contrary. The specialist in research and development in the industry has rarely been successful, whereas the boy who had a good fundamental knowledge of science and who was not anxious to specialize in any particular branch was easily adaptable to any research investigation and was frequently highly successful in his work.

The difficulty seems to lie in a lack of appreciation of the time necessary to make a specialist. The prominent specialists to-day have spent their entire lives acquiring the necessary knowledge to attain the position they now occupy. Four to seven years in a university will never produce a specialist of any importance.

The industries appreciate this condition, and there is a marked tendency in the last two or three years on the part of research directors and employment managers to ask for students who have had a thorough fundamental education in the three common sciences—mathematics, physics and chemistry. To-day they are specifically requesting that no specialized work of any kind be required in the curriculum. There is a marked tendency on the part of these industrial men to select for research and development boys who have been trained in the chemistry or chemical engineering curricula simply because these boys are better educated in the fundamental sciences. The engineering student is being used as an operator in the plant or as a mechanic in the development division. The young physicist is used sparingly in the research laboratory and could be used to a far greater extent if he would be willing to acquire a fundamental knowledge of chemistry.

This refusal on the part of the engineering student and the physicist to accept chemistry as an important study is very interesting from a psychological standpoint. On the other hand, the student of chemistry is very anxious to acquire all the physics that he possibly can. He is even willing to take as an elective course something which involves the application of physics, for example, courses in mechanical engineering and electrical engineering. He does not, however, consider these courses of great fundamental importance even though they may be extremely interesting.

It is also interesting to note why it is that specialization in education as regards applied science is often fatal in research work. The reason is extremely simple. The research problems of industries refuse to stay within the narrow limits of a definite applied science field. Steel manufacturing, for example, may involve problems in bacteriology. One would hardly criticize the young man who was going into steel manufac-

ture if he failed to take a course in bacteriology.

Another factor involved in specialized education is the question of placement of the graduate. It is the common occurrence that a young man who is trained for one particular industry has a very good chance to go into some other industry. Over half of the graduates of one of our most specialized engineering institutions go into a different line from the one for which they were trained.

Some years ago the electrical engineering department in one of our universities took over the problem of investigating the cause and prevention of failure of electric cables. The investigators were electrical engineers and they found, first of all, that it was necessary to devise a machine that would detect insulation flaws in a cable before it was put in service. This proved to be a rather difficult problem. A physicist well trained in electrical physics was called on to aid the investigators. Finally the problem of producing a testing machine for this purpose was solved. Then it became necessary to investigate the cause of insulation failure after the cable had been in use for a period of time. It was hoped that a method of testing could be devised that would predetermine the failure of insulation after a period of use. Chemists were added to the investigational staff, and this work is now in progress. It may be necessary to add botanists and other scientists before the problem is finally solved.

For many years ice manufacture in this country has been in the hands of refrigerating engineers as far as its technical development is concerned. These gentlemen are the type of men who have confined themselves largely to this one industry. Naturally their knowledge of physics and chemistry on the whole is limited. Development of the refrigeration industry has been along mechanical lines. At the present time in this country there are probably ten thousand ice plants that are operating at a very low efficiency because of water difficulties. The amount of the salt and the character of the salt present in the water determine whether or not a clear salable cake of ice can be made by ordinary methods. Distilled water is expensive, but is often necessary in localities where the raw water is not fit for ice manufacture.

Recently a research investigation headed by a physical chemist has been undertaken to study the water treatment for ice manufacture. In less than a year, treating the subject from a fundamental scientific standpoint, it was discovered that all waters can be so acted upon that they will make satisfactory, clear, transparent ice without resorting to distillation. A study of crystal growth showed the cause of opaque ice and also indicated several methods of prevention. A study of salt solubility resulted in a new method of removing sodium salts from water even when present in relatively small quantities without resorting to expensive reagents. It is interesting to remember that this investigation brought results within a year which will completely revolutionize a large proportion of the ice plants in this country, and that this research work was done by a young man who had a fundamental training in science but who had never seen the inside of an ice plant and who was not even familiar with any phase of refrigerating engineering.

For many years steam boilers in this country have blown up for one cause or another. Some years ago a peculiar kind of cracking was noticed in boiler shells which often proved disastrous. This type of cracking, now known as embrittlement, has been found in a great many boilers throughout this country and abroad. Mechanical engineers and metallurgists have made serious attempts to solve this problem without any apparent success. A few years ago

an investigation was started headed by an industrial chemist, a young man who had a thorough training in science and some research experience in various industries. To-day the cause is known to be concentration of caustic in the boiler water within a seam coupled with physical stress. The prevention is quite obvious. It is necessary to precipitate within this seam some solid material which is inactive towards the steel but will prevent accumulation and concentration of sodium hydroxide in the same space. A fundamental study based on the solubilities is all that is necessary to give a thorough understanding of the problem and indicate a satisfactory remedy.

There are many other cases which indicate quite clearly the importance of a fundamental training in research involving great industrial problems. An excellent recent example is the determination of the cause of corrosion by flue gases in our great power-houses. It has always been thought that sulphur oxides or sulphuric acid was the primary cause of corrosion of economizer tubes, etc. A fundamental study by a young man thoroughly trained in chemistry, physics and mathematics has indicated that sulphuric acid alone is of very little importance; that a solid material, ferric sulphate, is largely responsible for the corrosion of the steel tubes.

It is interesting to note that the type of problems mentioned above when once successfully solved represent an actual financial return of over a million dollars per year. This sum does not represent the entire benefit derived from such research but represents only the benefit derived by a single company from a single research project. Furthermore, the amount represents the tangible value of the benefit and does not involve such items as good-will.

There seems to be no question but that the research worker, young and inexperienced though he may be, who is well trained in fundamental science is quite able to do research work which has immediate application and is of great financial value.

If one is willing to recognize the above statement, it then becomes an interesting topic of discussion as to why our educational institutions should continue to train a great many bright, energetic young men in applied subjects which they have little or no chance of ever using and at the same time fail to train them in the fundamental sciences. Previously it has always been maintained that the young man who has been trained only in the fundamental sciences is unable to do work of practical importance. Experience in the last few years, especially in the chemical and allied industries, has proved this statement to be absolutely incorrect. These industries have found that only the young man who is giving his entire time and attention to fundamental subjects has been equal to the task set before him in the research and investigational department of our great industries. Many of the industrial executives appreciate this fact, as is illustrated by the tremendous demand for a young man trained in the fundamentals. The universities, on the other hand, have been slow in coming to this conclusion, and we still find enormous sums of money spent for the education of youths along the so-called practical lines. These boys end up as operators and usually finally leave their profession for a business career in order to make more money and at the same time have an opportunity to utilize their natural ingenuity.

This is not exactly a pleasant fact to face. Furthermore, we can not hope that our great universities will change over abruptly in the near future to a more sane view-point of education. As in all large institutions, developments within their organization are slow. It will take many years before the principal educational institutions in this country will realize that a broad training in the fundamental sciences is far superior to premature specialization for the boy who wishes to do industrial research.

SOMETHING ABOUT VITALISM AND MECHANISM

By EDGAR F. GROSSMAN
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THERE is life in a chunk of copper. Must we revere it, add its perplexities to those things which transcend our understanding? Should we accept it on a par with animal and plant life, describe and index it? Or can we ignore it, turn it over to the vitalist, the mechanist, and quietly watch the ensuing controversy? Rather than be served with predigested mental food let us examine the dogmas of the past, the tenets of the present.

Disregarding earlier culture than that of the Greeks, we are led to believe that many perplexing phenomena were given anthropomorphic or mythological explanations. From these explanations a crude form of science emanated. Then followed a more critical observation and study of the phenomena of the heavenly bodies, the first evidence we have of scientific ideas, which laid the foundation for astronomy, a science. Nevertheless, it was not until Aristotle (384–322 B. C.) advanced the first pure line of reasoning that mythology began to give way to science. Beginning at this point, I shall try to catalogue some of the more important scientific advances made by man in approaching our modern concepts, since it is altogether through the development of science that the vitalist and the mechanist became convincingly contradictory.

Aristotle, cited by the vitalist, upheld the following concrete views: That the universe is made up of nature, God and man; that nature, definite combinations of the four elements classified by Empedocles (450 B. C.) as earth, water, air and fire, plus Aristotle's thoughtful addition of ether and stars, made up animals, plants, water, earth, the moon and stars; that God is the cause of known effects, and man is a combination of the natural and divine; that plants are organisms with a nutritive soul; animals, organisms which have a nutritive, sensitive, oretic and locomotive soul; and man, an organism which has the aforementioned characteristics plus a rational soul, styled the intellect; and finally that it is the intellect through which man approaches God. What a paradoxical nicety!

Though the advances made by Aristotle and the many subsequent steps hesitatingly taken by science have been summarily retracted, it is interesting to note that the contributions made by Euclid (third century B. C.), who is regarded as either the discoverer or compiler of Euclidean geometry, continued in use for twenty centuries. It is a startling fact that now, however, we are forced to admit that Euclidean geometry is used as a matter of academic convenience only, since we must rely on another system of geometry to include the phenomena of the universe. We must now take cognizance of the geometrical difficulties peculiar to each of the other planets.

Equally interesting is the origin of mechanics and hydrostatics which is identified with Archimedes (287–212 B. C.), who presented two axioms: First, that equal weights placed at equal distances from the point of support of a bar will balance; and second, that equal weights placed at unequal distances do not balance, but that which

hangs at the greater distance descends. How easy and diabolical it would be at the present time to confuse Archimedes by introducing magnetic or electric influences, which were unknown to him!

Though Lucretius (98–55 B. C.) was essentially a poet, it is quite possible that he reflects the ideas of his contemporaries in stating that all forms of life merely appeared, while only those fittest to survive persisted and reared offspring. He furthermore denies the doctrines of supernatural government of the world and a future life. These ideas, ignored through centuries, appear to be somewhat similar to those held by some of the present-day emergent evolutionists.

The Dark Ages, or perhaps more accurately the period of ecclesiastic enlightenment, took firm hold on thought and put an abrupt stop to any undesirable controversy between vitalists and embryo-mechanists. Likewise the use of experimental methods for exploring the secrets of the natural phenomena was completely discouraged because experimentation was considered a danger to theological orthodoxy. A review of this attitude of intolerance, which so thoroughly stagnated scientific research, undoubtedly antagonizes many modern scientists to such a degree that they unhesitatingly discard the vitalistic view-point, feeling that vitalism is too closely bound to theology and metaphysics. There is a feeling of tolerant fondness, however, for the alchemists, who, even though their experimental efforts were tinged with mystical analogies, nevertheless carried on experimental work for over three hundred perilous years, perilous merely because their work was not accepted by orthodox theology.

A forward step was taken in the thirteenth century when Aristotle's philosophy, being duly reconciled and adopted by Christian theology, was reimported into the schools of Europe. Roger Bacon (1214–94) showed a keen intellect in working away from theology and metaphysics and in pursuing a study of physical science by experiment in the Aristotelian way. He fought the cultivation of science based on arguments deduced from premises resting on authority or custom, gave himself up to experimental research and lived to be eighty years old!

The fifteenth and sixteenth centuries, the Renaissance, ushered in many startling scientific discoveries. Chief among the factors which made such discoveries possible were the temporary diminution in power of the papacy, printing, the recovery of the Greek language and the consequent spread of the naturalistic view of the universe which had been current among the Greeks, instead of the mystical view expounded by the medieval schoolmen and ecclesiastics. Scientific research consequently prospered under the leadership of such men as Leonardo da Vinci (1452–1519), who, besides exhibiting many other accomplishments, followed mathematical and physical research, grasping hold of the laws and applications of mechanical forces; Copernicus (1473–1543), who developed the heliocentric theory; Francis Bacon (1561–1626), who set out to gain knowledge through experimental research as a corrective to medieval philosophy; Galileo (1564–1642), who paved the way for Newton by opening the science of dynamics, and William Harvey (1578–1657), who discovered the significance of blood and its circulation.

Newton (1642–1727), by discovering the laws of gravitation, brought the solar system into the cognizance of known dynamical principles. James Hutton (1726–97) and Charles Lyell (1798–1875), the founders of geology, expanded knowledge in time as enormously as Newton had expanded knowledge in

space. Laplace (1749–1827), joining in the tireless effort of scientists to eliminate the mystical, advanced the idea of a primitive state of nebulosity from which, by the action of known dynamical processes, the sun and planets would be evolved. Lagrange (1736–1813), a mathematician, fitted the theory of mechanics to certain formulas. By the development of the calculus of variations he largely verified the Newtonian theory.

Galvani (1737–98), physiologist, correlated the relations of animal functions to electricity, while Volta (1745–1827), a physicist, conducted experiments on contact electricity, and thus many more mysterious body functions were made comprehensible. Another step towards mental clarification was taken by Lavoisier (1743–94), a chemist, who overthrew Stahl's (1660–1734) phlogistic doctrine and broke the theory that redistilled water would yield earth. One by one the inexplicable mysteries of life which so grandly transcended human understanding were stripped of mysticism and subsequently clothed in substantial scientific theories.

Lamarck (1744–1829) explained new species on the theory of the effect of use and inheritance of acquired characteristics. Darwin (1809–82) offered survival of the fittest and occurrences of "sports." Evolution, then, became something which can make the theories of origin intelligible. Many other mysteries were removed by Mendel (1822–84), whose work on inheritance was rediscovered in 1901. The sacredness of heredity yielded to a mechanistic explanation—the theory of the gene, together with the concepts of the influences of environment, presented formidable weapons for the mechanist. The vitalist, though, can still challenge the inherited intellect to explain itself—demand an explanation, mechanically, for the intellect which Aristotle held to be "that through which man approaches God."

Our understanding of the nature of a bar of copper was made much clearer by Dalton (1766–1844), who developed the atomic theory. Ampère (1775–1836) established the field of electrodynamics from his work on electricity and magnetism. Wohler (1800–82) dealt "vital forces" a blow by artificially preparing urea, thereby breaking down the barrier held to exist between organic and inorganic chemistry, between life and non-life. Thereupon the chasm between a bar of copper and animal life was greatly lessened and the idea of spanning the rift was no longer held to be an enormity.

Faraday (1791–1867) cleared up induction of electric currents and electromagnetism. It is interesting to note that Faraday, eminently successful in experimental research, held a distinct belief in God from whom he believed emanated a power above us. He consequently found nothing incompatible in the idea of things that can be known by man-spirit and higher things that can not be known by that spirit.

Stokes (1819–1903), Bunsen (1811–98) and Kirchhoff (1824–87) discovered that the spectroscope gave a means of investigating the chemical composition of the sun and stars, and so brought another set of phenomena under the control of terrestrial experiment, thereby removing the marvels of the firmament which had completely transcended our understanding.

Schleiden (1804–81), before engaging in the obscurities of philosophical and historical studies, discovered cells and the nucleus and determined that a nucleated cell is the only original constituent of the plant embryo. Schwann (1810–82) established unexpected accord in the plant and animal cell and nucleus, hence the cell theory and foundation of modern histology. Virchow

(1821–1902), from studies of cellular pathology and classification of tissues, developed the science of pathology. He also placed the science of anthropology on a sound critical basis. These discoveries naturally allowed animal and plant life to be unified and even supported the view that man was an animal—all this without the hue and cry of heresy.

Pasteur (1822–95) ended the dispute on wholesale spontaneous generation. He not only revolutionized surgery but instigated studies in preventive and curative medicine. Not so well known and of less pertinent value to us legally is the fact that he created a new era in the brewing and wine-making industries. Weismann (1834–1914) developed the germ-plasm theory of heredity and with that indicated an earthly immortality of protoplasm—if we must have immortality.

Gibbs (1839–1903), the founder of chemical energetics, was the first to apply the second law of thermodynamics to the exhaustive discussion of the relation between chemical, electrical and thermal energy and the capacity for external work. J. J. Thomson (1856– ——), by continuing Faraday's work, developed the electron, and Lorentz (1853——) formed the theory of electrons within the atom. He suggested occasional instability of the atom—radioactivity—hence the chemical atom, hitherto believed indestructible and eternal, has succumbed to evolution.

Maxwell (1831–79), by studies of the properties and velocity of propagation of light and electromagnetic waves, decided they were identical, thereby making light an electromagnetic phenomenon. Planck (1868–) studied radiation and advanced the quantum theory, namely, that emission of heat radiation proceeds discontinuously, in quanta, while absorption is continuous. Lately, however, the applications of the revolutionary quantum theory are being critically questioned.

Loeb (1859–1924) aimed at the real distinction between living and dead matter. His working hypothesis was that all living things are chemical machines and their workings are open to the same mechanistic explanation as are those machines made of inert matter. His experimental researches with tropisms and artificial parthenogenesis yielded much material for the mechanist.

Sir Oliver Lodge (1851–) undertook to reconcile science and religion. His energies, first devoted to pioneer work in the field of wireless telegraphy, later became involved in psychical research, in which field he endeavored to discover a means of communication with the dead. A quotation, however, will acquaint us with Lodge's critical attitude.

> Speaking of cohesion, Sir Oliver Lodge once remarked that it was as yet an inexplicable fact that when one end of a rod is pushed the other end moves, to which *Punch* retorted that it was an equally inexplicable fact that when one end of a man is trodden upon the other end shouts.[1]

There, for the majority, ended a serious contemplation of Lodge's challenge.

Many other workers contributed information which led away from the mysterious unknown. Energy was studied and became as evident as mass, and both mass and energy in the universe were held to be constant, until the introduction of Einstein's theory of relativity. Einstein is now said to have succeeded in devising mathematical formulas which bring under a single set of laws the phenomena of electricity and magnetism with those of gravitation. Undoubtedly science has progressed rapidly since the adoption of research methods demanding observation, hypothesis, deduction and experimental verification.

[1] Swann, *Science*, November 2, 1928.

With each scientific discovery the mechanist naturally feels that the ultimate explanation of the hitherto mysterious phenomenon is fundamentally a mechanical one. The ease with which a phenomenon can be explained and understood when terms of mechanical conceptions are employed tends to convince the mechanist that he is presenting the most logical explanation available: this in noble contrast to the vitalist who must abide by a belief in the inexplicable, life. Ever since the adaptation of mechanical means of supplanting our muscular energy, we have been inclined to view force as a mechanical conception. Though magnetism or electricity, completely unknown and miraculously avoided, did not confuse Archimedes in crystallizing the idea of mechanics and hydrostatics, his followers were mystified and misunderstood until they explained these phenomena in terms of mechanics. Consequently the immediate difficulty facing the mechanist is that, though a greater signification may be reached by reducing all possible phenomena to mechanical conceptions than by employing mechanics in terms of electricity, magnetism or gravitation, mechanics is not philosophically the most fundamental science.

The main question of vitalism, according to Driesch,[2] is whether the purposiveness in those processes is the result of a special constellation of factors known already to the sciences of the inorganic, or whether it is the result of an autonomy peculiar to the processes themselves. He used the term *static teleology* to imply the meaning held by the mechanistic theory of the organism, and *dynamic teleology* to signify the vitalistic theory, "autonomy of vital processes."

The vitalists are subjected to such conditions as these: that all believers in epigenesis are vitalists; that many "unwelcome adherents" claim to be vitalists; that the theory of vitalism has died or has not died, according to the conviction of the vitalist, to be recrystallized in neovitalism. In other words, the vitalistic theory has changed in concept as much as science has; in fact, so great are such changes that a person's scientific or vitalistic ideas of a decade ago are not subscribed to to-day. That the mechanists are faced with similar difficulties is to be expected.

In discussing the play "RUR" with a friend, I pointed out that in the play mankind had created mechanical men, robots, which carried on all necessary and irksome tasks until they revolted and killed all mankind. It was then merely a matter of time until the robots themselves would rust and wear out. We granted the possibility of making such robots, even that robots could be made which could make "baby robots," but balked at the idea of making robots which could design or create other distinct types of robots. Mechanics then, though carried to an astounding degree, would nevertheless lack a vital something.

W. F. G. Swann, a physicist, gives a most timely warning to those who seek to become extreme mechanists. He divided the activities of living things into three classes as regards their relation to physics. First, the class which is understandable in terms of physics or chemistry, such as cell osmosis; second, the class which has not been duplicated in the laboratory in such a manner as to provide a quantitatively satisfactory explanation of the actions of the organism, as many chemical reactions which take place in the non-living protoplasm but occur with increased velocity in the otherwise indistinguishable living protoplasm, and third, that class, if there be such a class, which comprises those phenomena of life which require a definite

[2] "The History and Theory of Vitalism," 1914.

appeal to a wider system of laws than those comprised under chemical or physical laws in the ordinary sense of the word. Quoting Swann:

> The fact that vital phenomena do not make themselves immediately evident in so-called non-living matter is no criterion as to the certainty of their complete absence. It is, in fact, not inconceivable that the existence of completely non-living matter as such would be unstable, and that the living activity might increase, perhaps slowly at first, but possibly at an increasing rate, until, at any rate in the presence of suitable conditions and environment, it finally attained a steady state in which there was a definite equilibrium between the living and the non-living matter.

Jackson, a mathematician, writes:

> Having been impressed at an uncritical age with the principle of the conservation of energy, I awoke to a painful realization that I did not know what energy meant, and the more I tried to find out, the more I was puzzled by the alleged importance of the conservation of so remote an abstraction, until it dawned on me in a flash of illumination that the importance of energy lay in the fact that it was the thing that was conserved. The discovery of the existence of such a unifying permanence by the creators of the science was one of the things that made mathematical physics possible. It is not apparent that there exists any small group of variables sufficient to characterize the phenomena of a living organism. A physical body is more or less homogeneous, or can be so considered for the purposes of argument. With an organism this is not the case. Statistical prediction deals with organisms in the mass, while our vital human concerns are with organisms as individuals; and the individual has a complexity of parts, which demand separate consideration with regard to their several functions. There is no prospect, humanly speaking, that we shall ever have methods for the practical handling of complicated differential equations in several dozen or several million variables. In the controversy between mechanist and vitalist, between behaviorist and subjectivist, the part of the mathematician must occasionally be the inglorious one of counseling moderation. He is too familiar with the limitations of calculations to see in them, or in the present limitations of any science, need for invoking supernatural intervention. But when he considers that an exhaustive discussion of the dynamics of a single atom of helium transcends our powers for the time being, and lifts his eyes from an atom of helium successively to an atom of carbon, a molecule of sugar, a molecule of protoplasmic substance, a living cell, a toadstool, a tree, a guinea-pig and a professor of mathematics, he does not look for any early reduction of the laws of life to a system of differential equations which he can integrate.

It appears, then, that mechanism can not withstand critical analysis. Why should it, when the working principles of scientists can not be said to be founded on a single infallible assumption? On the other hand, the vitalist who revels in the fallibility of the human mind is nothing but a mystic: he shirks mental activity and succumbs to mental indolence, or else he embarks on circuitous mental adventures. The vitalist, though, who adopts the doctrine "that life is the basic reality, of which everything else is a form or manifestation" must be considered with respect, especially if he is able to differentiate life from non-life.

Confused as we are by the ineptitudes of vitalism and mechanism, intimidated by the crashing of one doctrine after another, crushed by the restriction of mental facility, still we dare to affirm and deny. We may grandly admit that there is life in a chunk of copper, thereby avoiding the possibility of being dubbed "dogmatic." We can not believe, however, that the life in the copper would worry about appearing to be dogmatic.

MATHEMATICS IN THE SOCIAL SCIENCES[1]

By Professor IRVING FISHER
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THE invitation to deliver this lecture was accepted chiefly because of my veneration for J. Willard Gibbs, whose pupil I was forty years ago.

It was by accident rather than by design that my own life work was diverted from mathematical physics and mathematics, which it was my privilege to study under Gibbs, and was turned, instead, toward the application of mathematics to the social sciences. While I have lost touch with the subject of which J. Willard Gibbs was a master, the debt which I owe to him and the help which my studies with him have afforded me even in the field of the social sciences can never be forgotten.

I hope, therefore, it may not be amiss to precede what I have to say on mathematics in the social sciences by a reminiscent statement of my personal impressions of Gibbs himself. J. Willard Gibbs towered head and shoulders above any other intellect with which I have come in contact. I had a keen realization of his greatness even in those formative years in Yale College and the Yale Graduate School. But this keen realization has grown even keener as the years have swept by, not only because of the increased evidence of the fundamental value of Gibbs's work in his own chosen field but also because in my own consciousness, after so many details have dropped from memory, there persists all the more clearly the strong impression which Gibbs's personality and teaching made upon me.

In saying this I do not think I can be accused of undue enthusiasm simply from the loyalty of a pupil to his teacher, especially in view of the statements of Lord Kelvin and others which virtually rank Gibbs as the Sir Isaac Newton of America. Lord Kelvin said, when visiting at Yale a few years ago, that "by the year 2000 Yale would be best known to the world for having produced J. Willard Gibbs."

One of the most striking characterizations of Gibbs was recently made by Dr. John Johnston, now with the United States Steel Corporation, then professor of chemistry at Yale, in his address on Gibbs delivered at Yale University two years ago. He stated that no result of Gibbs's work had yet been overthrown, and that, in this respect, Gibbs seems to stand unique and supreme among the great scientists.

The English physical chemist, Professor F. G. Donnan, has said that "Gibbs ranks with men like Newton, Lagrange and Hamilton, who by the sheer force and power of their minds have produced those generalized statements of scientific law which mark epochs in the advance of exact knowledge. . . . The work and inspiration of Gibbs have thus produced not only a great science but also an equally great practice. There is, to-day, no great chemical or metallurgical industry that does not depend, for the development and control of a great part of its operations, on an understanding and application of dynamic chemistry and the geometrical theory of heterogeneous equilibria."

Professor Ostwald said, in the preface to his German translation of Gibbs's thermodynamic papers in 1892:

> The importance of the thermodynamic papers of Willard Gibbs can best be indicated by the fact that in them is contained, explicitly or implicitly, a large part of the discoveries which have since been made by various investigators in the domain of chemical and physical equilibrium and which have led to so notable a de-

[1] The J. Willard Gibbs lecture before the American Mathematical Society, American Association for the Advancement of Science, Des Moines, Iowa, December 31, 1929.

velopment in this field. . . . The contents of this work are to-day of immediate importance and by no means of merely historical value. For of the almost boundless wealth of results which it contains, or to which it points the way, only a small part has up to the present time [1892] been made fruitful.

Sir Joseph Lamor said:

This monumental memoir ["On the Equilibrium of Heterogeneous Substances"] made a clean sweep of the subject, and workers in the modern experimental science of physical chemistry have returned to it again and again to find their empirical principles forecasted in the light of pure theory and to derive fresh inspiration for new departures.

We think no less of Gibbs's greatness because he himself showed so little consciousness of it. He must have realized the fundamental character of his work. But his pupils remarked his profound modesty and often commented on it. His chief delight was in truth-seeking for its own sake, and he was so intent on this search that he had no time even to think of emphasizing the originality or value of his own addition to the great vista of truth over which his mind swept. Doubtless he often did not know or greatly care where the work of others ceased and his own began. He did not always wade through the literature which preceded his own scientific papers. I remember hearing him say that when he wanted to verify another man's results he usually found it easier to work them out for himself than to follow the other man's own course of reasoning. This was said without any affectation, but simply in a jocular vein, as by one who would escape a difficult task by going his own way. But even though it may be difficult to disentangle what was original in Gibbs's work from what was anticipated by others, surely no competent person doubts to-day that he founded a new era in physics and chemistry.

Because of his retiring disposition and the theoretical nature of his work, he was, during his lifetime; almost unknown except among a few special students. The majority of students at Yale in my day did not know of his existence, much less of his greatness. And there were far fewer people in America than there were in Europe who could appreciate what he was doing.

His work was more promptly recognized in Germany. When I studied in Berlin in 1893, and was asked under whom I had studied in America, I enumerated the mathematicians at Yale. To my mortification not one of the names was known to those Berlin professors, until I mentioned Gibbs, whereupon they were loud in his praises. *"Geebs, Geebs, jawohl, ausgezeichnet!"*

Even to-day, Gibbs illustrates the rule that a prophet is not without honor save in his own country. As Professor Johnston noted, the fiftieth anniversary of the publication of the first part of Gibbs's great work "On the Equilibrium of Heterogeneous Substances" was signalized in Holland by the publication of a Gibbs number of their chemical journal. This contained contributions from Dutch authorities as well as from French, German, Canadian, Norwegian and English authorities—but none from an American!

It is true, however, that at Yale we have finally established a Gibbs fund for a lectureship to be filled by visiting professors and that a new complete edition of his works has been issued by Longmans, Green and Company. It is also planned to issue two volumes of commentation on Gibbs's work to make its chief results more accessible to the general scientist. I am proud to have played a part in securing these. May I take this opportunity to say that I am also proud to have been included among the J. Willard Gibbs lecturers? And may I congratulate the American Mathematical Society on being the organization to found this lectureship, although Gibbs was professedly not so much a mathematician as a physicist. The only other Gibbs lectureship seems to be that at the Mellon Institute in Pittsburgh.

The Chicago Section of the American Chemical Society awards a J. Willard Gibbs medal annually, the recipient of which makes an address.

Presumably Gibbs's greatest contribution to science was his application of the laws of thermodynamics to chemistry. He made this almost a deductive science. Professor Bumstead said of his work:

> To an unusual extent, among the sciences which appeal to experiment, it can be, and has been, cast in a deductive form. Sir Isaac Newton said that "it is the glory of geometry that from a few principles it is able to produce so many things." Thermodynamics shares in this kind of glory; it has only two fundamental principles, of which the first is a statement of the conservation of energy as applied to heat, and the second states the fact (so deeply founded in general experience that it seems almost axiomatic) that heat will not, of itself, flow from a body at a lower temperature to one of a higher temperature. From these two simple principles, by an almost Euclidean method, a surprising number of facts and relations between work and heat, and various properties of bodies were deduced about the middle of the last century.

J. Willard Gibbs was certainly a master at producing many deductions from a few general principles. And it was just because of the generality of the principles from which he always insisted on starting that he succeeded in reaching such a wealth of conclusions.

In fact, it has always seemed to me that Gibbs's chief intellectual characteristic consisted in his tendency to make his reasoning as general as possible, to get the maximum of results from the minimum of hypotheses. I shall never forget, and have often quoted, an aphorism used by Gibbs, whether or not original with him, to the effect that "the whole is simpler than its parts." For instance, when he had a problem involving coordinates he preferred to employ an *indeterminate* origin, maintaining that his results were thereby rendered simpler and easier than if he took the origin at some apparently more convenient but special point in relation to the crystal or other conformation which he was discussing. When the origin is indeterminate it automatically effaces itself from all the general relations deduced.

Many if not most other investigators instinctively seek to solve special cases before attempting to solve the general case. Sometimes they pay a big penalty in needless experimentation. I remember Professor Bumstead, my fellow student at Yale, recounting with relish a conversation that Gibbs was reputed to have had with a youthful investigator who had made a laborious experimental study of certain relationships and who was, with pardonable pride, telling Gibbs of his conclusion. After listening attentively Professor Gibbs quite naturally and unaffectedly closed his eyes, thought a moment, and said, "Yes, that would be true," seeing at once that the special result which this young investigator had reached was a necessary corollary of Gibbs's own more general results. For him, it required no experimental verification. The young man's work had, from Gibbs's view-point, been almost as much wasted as if it had been spent in a laborious set of measurements of right angle triangles on the basis of which measurements he should announce as a new and experimental discovery that the square of the hypotenuse is equal to the sum of the squares of the other two sides. It is worth noting that, though Gibbs did his work in the Sloane Physics Laboratory, he never, as far as I know at least, performed a single experiment. His life work, stupendous as it was, and based as it was on concrete fact, consisted exclusively in new deductions from old results, the full significance of which no one else had been able to derive.

In his effort to represent physical relations by geometrical models and to portray the theory of electricity and magnetism by geometrical methods, Gibbs encountered the need of a new vector analysis to replace the awkward analysis by Cartesian coordinates, requiring, as

that does, three times as many equations to write and manipulate as does vector analysis, not to say diverting attention from the lines and surfaces actually involved to their projections on three arbitrary axes.

To me the most interesting course I had with Gibbs was on vector analysis. He believed he had simplified the Hamilton system of quaternions, getting his cue from Grassmann's "Ausdehnungslehre." But he was so conscious of his obligations to Grassmann that he was reluctant to publish his own system, apparently doubting whether it possessed enough originality to warrant publication. He therefore had privately printed a syllabus of his system and this reprint was used by us in his class as a text. Only after many years did Professor E. B. Wilson construct a more elaborate text-book embodying Gibbs's principles of vector analysis.

It is a curious fact that, while Gibbs's work in thermodynamics was appreciated in German, his work in vector analysis was not. I remember the comment of Professor Schwartz at Berlin, when I undertook to defend Gibbs's vector analysis: *"Es ist zu willkürlich."* The Germans felt in honor bound to restrict pure mathematics to mere elaboration of the proposition that one and one makes two. Starting with this proposition, by successive additions or subtractions of unity, we may, of course, by going forward, obtain all the positive integers; this is addition. Reversing, we obtain zero and the negative integers; this is subtraction. Then, by applying repeated addition or multiplication and repeated subtraction or division, repeated multiplication or involution and repeated division or evolution, we arrive at fractions, surds, imaginary quantities and finally the "complex variable" $x+y\sqrt{-1}$. But beyond this, by such processes no more general form of magnitude can possibly be derived; for, if we operate on a complex variable by addition, subtraction, multiplication, division, involution or evolution, under the recognized rules of algebra, we obtain simply other complex variables and nothing else whatsoever. Only by changing, or as the German critics would say, by violating, the fundamental rules of algebra faithfully followed in the above processes, such as the rule that $a\times b$ is equal to $b\times a$, is it possible to enter into any other realm of mathematics than that of the complex variable.

When I reported these criticisms to Gibbs, his comment was that all depends on what your object is in making those sacrosanct rules for operating upon symbols. If the object is to interpret physical phenomena and if we find we can do better by having a rule that $a\times b$ is equal not to $b\times a$ but to *minus* $b\times a$, as in the multiplication of two vectors, then, he said, the criticisms of the Germans are beside the point.

The fact is that Gibbs, though a great mathematician, was not primarily interested in mathematics as such. His interest lay in its applications to reality—in the substance rather than the form. All his contributions to pure mathematics were sought and found not as mere proliferations of formal and abstract logic but as by-products of his work in interpreting the facts of the physical universe.

The far-reaching effects of Gibbs's work apply not only to inorganic physics and chemistry but also to the organic world. One of the most elaborate reviews of Gibbs and his relation to modern science is by Lieutenant Colonel Fielding H. Garrison, M.D., assistant to the librarian of the Army Medical Library, Washington, D. C., in which he shows, among other things, the application of Gibbs's work to the equilibrium of heterogeneous substances in general physiology.

Despite Gibbs's retiring disposition and his disinclination for general society he was most cordial in his personal contact with colleagues and students and never seemed to lack time to give to any

one who chose to discuss the subject in which he was so deeply interested. He made on all a deep impression of kindliness. I well remember the remark of Percey Smith, now professor of mathematics at Yale, who was a fellow student of Gibbs with me, as we walked out of one of Gibbs's lectures, "What a *gentle* man he is!"

He enjoyed a joke, often laughed and excited laughter. He took pleasure in applying his mathematics in simple ways. One of his minor but fascinating papers before the Yale Mathematical Club was on the "Paces of a Horse," the writing of which was doubtless suggested by watching a horse which he had just purchased. Probably no one else ever put a horse through his paces as scientifically or amusingly as Gibbs did in that paper.

Gibbs himself never contributed to the social sciences. Apparently I am the only one of his pupils who, after first doing some teaching in mathematics and physics, became professedly an economist, although Professor E. B. Wilson, Gibbs's chief interpreter as to mathematics, has taken a lively interest in many lines of social science and statistics and was this year president of the American Statistical Association.

After several years' graduate study, partly in mathematics under Gibbs and partly in economics under Sumner, the time came for me to write my doctor's thesis and I selected as my subject, "Mathematical Investigations in the Theory of Value and Prices." Professor Gibbs showed a lively interest in this youthful work, and was especially interested in the fact that I had used geometric constructions and methods including his own vector notation.

The late Professor Allyn Young, of Harvard, also made occasional use of vectors in his economic work. Another economic student and writer, a brilliant young Norwegian, Professor Ragnar Frisch, has latterly used the vector notation and says he could scarcely think without it. Professor Frisch will this year be visiting professor at Yale from the University of Oslo.

It is one of the handicaps of mathematics in the social sciences that there are so few who are trained in both lines for such study, and this particularly applies to any applications of Professor Gibbs's vector analysis. If vector analysis should become more widely understood and used by students in the social sciences, doubtless it would be more generally utilized, at least as a vehicle for thought.

Occasionally, and increasingly, the ideas and notations of the differential and integral calculus are applied by mathematical economists and statisticians. But, of course, most of the mathematics employed in the social sciences consists of simple algebra. There is a saying which, by the way, was quoted by Gibbs in his address on "Multiple Algebra" that "the human mind has never invented a labor-saving machine equal to algebra."

There are several fairly distinct branches of social science to which mathematics has been, or may be, applied. The chief of these may be distinguished as (1) pure economics, (2) the "smoothing" of statistical series, (3) correlation and (4) probabilities, all of which overlap to some extent.

My own chief interest in social science, from a mathematical point of view, has been in the first of these four groups, pure theory.

When I began my work in this field in 1891, mathematics in economic theory was looked at askance, despite the fact that many years before, as early as 1838, Cournot had written his brilliant "Researches into the Mathematical Principles of the Theory of Wealth." This book later greatly stimulated Professor Edgeworth, of Oxford, and Professor Marshall, of Cambridge, and to-day is ranked among the economic classics. The same may be said of Jevons's "Theory of Political Economy" pub-

lished in 1871. But in 1891, when my own economic studies began, even the work of Cournot was almost unknown to economists, and that of Jevons was little used. If one will turn the pages of the main economic literature of 1891 and earlier, he will find practically no formulas and no diagrams. But Walras and Pareto in Switzerland and Pantaleoni and Barone in Italy, Edgeworth and Marshall in England, Westergaard and Wicksell in Scandinavia and a few other students in other countries were using and defending the new method.

When, at the request of Professor Edgeworth, I read a slightly mathematical paper on the "Mechanics of Bimetalism" before the Economic Section of the British Association for the Advancement of Science at Oxford in September, 1893, I well remember how, in the discussion of that and other mathematical papers, Professor Edgeworth was, as he expressed it, "damped" by the unfriendly criticism of these new methods by Professor Sidgwick and others.

But little by little, the usefulness of mathematics has come to be appreciated. Besides the older writers already mentioned and Auspitz and Lieben, whose work on price determination of 1889 was one of my first inspirations, there have gradually come into this field many younger writers among whom may be mentioned Professor Henry L. Moore, of Columbia University, Professor J. H. Rogers, of the University of Missouri, Professor C. F. Roos, of Cornell University, Professor Griffith C. Evans, of Rice Institute, Professor Henry Schultz, of the University of Chicago, Professor Harold Hotelling, of Stanford University, W. A. Shewhart, of the Bell Telephone Laboratories, Professors J. Maynard Keynes, A. C. Pigou and Arthur L. Bowley, of England, Professors Albert Aftalion and Jacques Rueff, of France, Ladislaus von Bortkiewicz, of Berlin, Dr. Otto Kühne, of Germany, Professor Wl. Zawadski, of Poland, Professor E. Slutsky, of Russia, Professor Gustav Cassel, of Sweden, Professor Ragnar Frisch, of Norway, Dr. Willem L. Valk, of Holland, Professors Corrado Gini and Luigi Amoroso in Italy.

And besides the fact of such accessions to the ranks of the small band of professed mathematical economists is the even more significant fact that economists in general have not only ceased decrying mathematics but are, in many cases, making some slight use of it themselves.

The late Professor Marshall, of Cambridge University, was one of the first to perceive what was happening. He said:

> A great change in the manner of thought has been brought about during the present generation by the general adoption of semi-mathematical language for expressing the relation between small increments of a commodity on the one hand, and on the other hand small increments in the aggregate price that will be paid for it, and by formally describing these small increments of price as measuring corresponding small increments of pleasure. The former, and by far the more important, step was taken by Cournot;[2] the latter by Dupuit[3] and by Gossen.[4] But their work was forgotten; part of it was done over again, developed and published almost simultaneously by Jevons and by Carl Menger in 1871, and by Walras a little later. Jevons almost at once arrested public attention by his brilliant lucidity and interesting style. . . .
>
> A training in mathematics is helpful by giving command over a marvelously terse and exact language for expressing clearly some general relations and some short processes of economic reasoning, which can indeed be expressed in ordinary language, but not with equal sharpness of outline. And, what is of far greater importance, experience in handling physical problems by mathematical methods gives a grasp, that can not be obtained equally well in any other way, of the mutual interaction of economic changes. The direct application of mathematical reasoning to the discovery of economic truths has recently rendered great services in the hands of master mathematicians to the study of statistical averages and probabilities and in measuring the degree of consilience between correlated statistical tables.

[2] "Recherches sur les principes mathématiques de la théorie des richesses," 1838.

[3] "De la mésure d'utilité des travaux publics" in the Annales des Ponts et Chaussées, 1844.

[4] "Entwickelung der Gesetze des menschlichen Verkehrs," 1854.

Mathematics serves economic theory in supplying such fundamental concepts based on the differential calculus and also through the process of differentiation solves problems of maxima and minima, as in the simple process of determining formally what is the price that the traffic will bear in order to make profits a maximum.

The chief realm of economic theory to which mathematical analysis of this kind applies is that of supply and demand, the determination of prices, the theoretical effect of taxes or tariffs on prices. The results can not always be reduced to figures but are often useful in terms of mere inequalities.

For instance, among the chief theorems shown mathematically by Cournot are the following: That a tax on a monopolized article will always raise its price, but sometimes by more and sometimes by less than the tax itself; that a tax on an article under unlimited competition always raises its price but by an amount less than the tax itself; that a tax proportional to the net income of a producer will not affect the price of his product; that fixed charges among costs of production do not affect price nor do taxes on fixed charges; that opening up free trade in a competitive article between two previously independent markets may decrease the total product.

Among the most surprising paradoxes discovered by the mathematical method is one shown by Edgeworth, that if a monopolist sells two articles, say first and third class railway tickets, for which the demand is correlated, it may be possible to tax the third class tickets, at a fixed amount each, with the result that the monopolist not only pays the tax but lowers the prices of both kinds of tickets.

Familiarity with mathematics will save many confusions of thought. For instance, it is just as important in economics to distinguish between a high price and a rising price as it is in physics to distinguish between velocity and acceleration. Rate of price change has important effects, both theoretically and in practice, on the rate of interest and on the volume of business.

Theoretically the rate of interest ought to be higher during a period of rising prices, or depreciation of the dollar, by an amount equal to the rate of depreciation, and it ought to be lower during appreciation.

Practically, however, the rate of interest is slow of adjustment and, what is more important, inadequate in adjustment. A mathematical statistical analysis of this slowness and inadequacy helps explain great business upheavals as shown in my new book on "The Theory of Interest." I may say here, parenthetically, though the case is somewhat different, that the recent crash in the stock market was, in large measure, the price paid for tardiness in raising the rate of interest which should have risen over a year ago but was held down artificially.

Again, mathematics will save the economic student and the student of accounting from the many confusions of double counting, especially in the intricate theory of income.

Another elementary, but important, use of mathematics in economics is in making sure that a problem is determinate by counting and matching the number of independent equations and the number of unknown quantities. A great deal of unnecessary misunderstanding has existed and still exists in economic science as to what determines the rate of interest or other magnitudes in economics. These misunderstandings would not exist if the contestants would take the trouble to express themselves mathematically. If we view the matter mathematically it soon becomes evident that one contestant has seen only one of the determining factors, and the other another, without either of them realizing that both are compatible and needed in a complete economic equilibrium. The concept of economic equilibrium in which many factors act and react on each other

is one of the chief elementary contributions of mathematics to economic theory, and one stressed by Cournot, Walras, Marshall, Pareto and Edgeworth.

Still another use of mathematics is in illustrating geometrically or analytically the fact that a price, or a "marginal utility," is a function not simply of one but of many variables, the function being purely empirical and incapable of analytical or arithmetical expression. In fact, the economic world is a world of *n* dimensions.

Thus the marginal utility of bread to John Doe is a function of his quantity not only of bread consumed, but of butter, sugar and numerous other variables.

I have myself tried to apply these and other mathematical ideas to the formal solution of the problem of prices of commodities, the rate of interest, the relation of capital to income, the purchasing power of money and what Simon Newcomb, the astronomer-economist, called the equation of societary circulation, now called the equation of exchange (the volume of circulating medium multiplied by its velocity of circulation is equal to the price level multiplied by the volume of trade per unit of time).

Most of these and other applications of mathematics to economic theory consist in short chains of reasoning. Professor Marshall had the impression that only short chains of reasoning could ever be expected in mathematical economics. He said:

> It is obvious that there is no room in economics for long trains of deductive reasoning: no economist, not even Ricardo, attempted them. It may indeed appear at first sight that the contrary is suggested by the frequent use of mathematical formulae in economic studies. But on investigation it will be found that this suggestion is illusory, except perhaps when a pure mathematician uses economic hypotheses for the purpose of mathematical diversions, for then his concern is to show the potentialities of mathematical methods on the supposition that material appropriate to their use had been supplied by economic study. He takes no technical responsibility for the material and is often unaware how inadequate the material is to bear the strains of his powerful machinery.

But as time goes on, there appear instances of somewhat longer trains of reasoning.

I may take an example from my own work. I have tried to show how it is possible to estimate numerically through suitable mathematical equations the velocity of the circulation of money. The formula for this was derived through a chain of mathematical reasoning requiring several links and embracing a considerable number of variables of which the chief are the volume of money in circulation, the annual flow of money into and out of banks and the annual cash payments to labor. This problem, by the way, of evaluating the velocity of circulation of money had been pronounced insoluble, and without mathematical analysis it might well be so considered. Incidentally, the calculations indicate that money in the United States circulates about twenty-five times a year. In other words, the average dollar stays in the same pocket about two weeks.

To turn to a different example, both Professor Ragnar Frisch and myself, by independent methods, both of them highly mathematical, have shown how, theoretically, under certain simple hypotheses, to accomplish the statistical measurement of "marginal utility" or desirability as a function of one's income. This would determine whether or not it is true that if one man has double the income of another his tax ought to be double, more than double or less than double in order that he should make the same sacrifice. In other words, it would supply a mathematical criterion by which to judge the justice of a progressive income tax.

I say "would" rather than "does" simply because as yet the statistics available do not seem adequate for any accurate evaluation. But Professor Frisch and I are both hoping to pursue this

study further. His and my preliminary results are not inconsistent. My own formula is derived by a chain of mathematical reasoning which results in expressing the ratio of the "marginal utility" of money for a person with a certain income to the "marginal utility" which he would have with a different income in terms of the following elements: those two incomes, the percentages which would be spent on food, rent, etc., under the two respective incomes and the index numbers of prices of food, rent, etc., relatively to another country, serving as a standard of comparison.

Mathematics also helps make clear the "dimensionality" of the magnitudes treated. Thus, the quantity of wheat, its price and its value are three magnitudes as unlike in dimensionality as time, velocity and distance. The rate of interest has the simplest dimensionality, being, like angular velocity, of dimension t^{-1}.

Mathematics helps us analyze time relationships in general, especially to avoid the old confusion between capital and income, the one relating to an instant of time, the other to a period of time.

Capital-income analysis is a development of the last two score years, but its roots go back generations. Every good treatise on algebra includes the formulas for capitalizing annuities and bonds, the formulas underlying the bond tables used in every broker's office.

While the development of mathematical economics from the theoretical side has been steady and impressive since I was a young man, it has by no means been so rapid as the development of the other three branches to which I have referred.

"Smoothing" statistical data, the fitting of formulas and curves to statistics, has, of course, been one of the aims of statisticians for many generations. In this way we have derived our mortality tables, the basis used by actuaries for calculating life insurance premiums.

I understand that the second J. Willard Gibbs lecture was by Robert Henderson on "Life Insurance as a Social Science and as a Mathematical Problem." The importance of this branch of our subject does not need to be emphasized in an insurance center like Des Moines.

Actuarial science is, of course, a development of the formulas for capitalization or discount, particularly as applied to annuities, combined with the introduction of the probability element based on mortality statistics. It is essentially an analysis of interest and risk. It could be, and perhaps some day will be, applied to other economic problems besides life insurance, as soon as statistics are adequate for assessing risk numerically in other realms than human mortality. In fact, one of the crying needs of economic science is a reliable basis for evaluating risks.

Concurrently with actuarial science has developed a science of mathematics of mortality in relation to population, extending at least back to the days of William Farr, superintendent of the statistical department of the registrar general's office of England half a century ago. To-day this science has been further developed by Knibbs, of Australia, Lotka and Glover in the United States, and others.

Recently with the development of statistics of industry the art of curve fitting by mathematical methods has grown very rapidly, and examples of it will be found in many current issues of statistical journals. I am, myself, with a collaborator, Max Sasuly, working on a new method of curve fitting aimed to avoid the use of any preconceived formula but letting the statistical data themselves write their own formula, so to speak.

One important phase of curve fitting which links it closely with the study of economic theory is the statistical evaluation of supply and demand curves. Among those who have worked in this

field are Professor Henry L. Moore, of Columbia University, Professor Henry Schultz, of Chicago University, Dr. Mordecai Ezekiel, of the U. S. Department of Agriculture, Professor G. F. Warren, F. A. Pearson and C. F. Roos, of Cornell University, and Professor Holbrook Working, of Stanford University. Professor Schultz was apparently the first to work out the statistical determination of the effect of the tariff on the price of an imported commodity—sugar.

The third group of mathematical work in the social sciences, the development of correlation, is closely associated with the name of Karl Pearson, of the University of London, who is still living. His correlation coefficient has become almost a standard procedure in economic statistics as well as in other sciences, including biology, in which he is primarily engaged. To-day many, if not most, economists, especially if they work in statistics, are making some use of such correlation coefficients. Through them they have been forced to adopt mathematical aids in spite of old traditions and prejudices.

Professor Warren M. Persons, formerly of Harvard, has worked out correlations with lag showing the interrelations of various economic phenomena in such a way as to serve the purposes of forecasting business conditions. A more elaborate method of correlation has been worked out by Karl Karsten, of New Haven, a private statistician, who has made tables of correlation between every pair of available series of economic statistics and has put these together by multiple correlation so as to predict any one of the series from all the others which are found to serve toward that end. He is now issuing regularly a forecast of commodity prices, of the volume of business, of stock market trends and of various other economic factors.

In the study of the so-called business cycle and forecasting future fluctuations, mathematical economists and statisticians have made increasing use of what is virtually differentiation or integration. Thus I have emphasized "price-change" as distinct from price, of which it is the differential quotient. Reciprocally, Mr. Karsten has applied the idea of "quadrature" to the relations of two statistical series where one is virtually derivable from the other by integration. This means if the curves are cyclical that they are related as are the curves of sines and cosines so that one curve is at zero while the other is at a maximum or minimum.

One development in this field in which I have been especially interested has been the study of the distribution of the lag. This appears to be a skew distribution, but nearly normal if time is plotted on a logarithmic scale.

As already indicated, risk is one of the fundamental elements in the mathematical analysis of actuarial science. It is also, in a different way, through frequency distribution, a fundamental element in correlation analysis. In fact, there have been more or less successful attempts by Karl Pearson to resolve a mortality curve into a sum of several frequency curves and by Arne Fisher to do the reverse—synthesize a set of frequency curves representing mortality from certain causes into the total mortality curve. It may also be pointed out that our second topic, curve fitting and smoothing, whether by least square methods or otherwise, is largely a study in probability.

All this brings us to the fourth chief branch of our subject, the mathematical analysis of probability in general in so far as this relates to social phenomena as embodied in statistics. This has been increasingly studied by many economists, especially the late F. Y. Edgeworth, editor of the *Economic Journal*. Also

mathematical statisticians such as G. Udny Yule, Arthur Bowley, R. A. Fisher, Sir William Beveridge, Truman L. Kelley, A. C. Whitaker, William L. Crum, Thiele and others have done much constructive work in this field.

Professor Vilfredo Pareto tried to work out a formula for statistics of incomes in relation to the number of persons possessing incomes of various sizes, and the Pareto curve has become quite famous. It has been shown, however, particularly by Professor Macaulay, of the National Bureau of Economic Research, that the Pareto curve is nothing but the "tail" of a probability curve, although Pareto himself had been loath to admit this. It is true that this particular sort of probability or distribution curve is not "normal" even if the abscissas are plotted on a logarithmic scale. It often happens in statistical series, especially where the frequency distribution lies between zero as one extreme and infinity as the other, that the frequency or probability curve while very skew on the arithmetical scale turns out to be nearly "normal" on the logarithmic scale.

I have, of course, by no means exhausted the list of applications of mathematics to economics, still less to the other social sciences. Many applications have been made which are not easily classified under the four heads I have noted, namely, pure theory, curve fitting, correlation and probabilities.

Of these other and miscellaneous applications, the most important, at least in the field of economics and statistics, seems to be that of index numbers. The theory and practice of index numbers have had a special fascination for many of us because they occupy a tantalizing position on the borderline between *a priori* rational theory and empirical makeshift and because of the many pitfalls encountered in their study. It is closely related to the subject of probability. In my book on "The Making of Index Numbers," I have tried to find the best formula for an index number out of several score available formulas.

It is also true, of course, that the last three divisions of our subject, curve fitting, correlation study and probability, traverse all fields of knowledge. They apply not only to my own branch of the social sciences, economics, but to all others such as sociology, anthropology and education, as well as to fields outside of social science such as psychology, biology, hygiene and eugenics. In all these we find a development of mathematical method. Each has its own special concepts, measures and principles, such as the cranial index of anthropology, the intelligence quotient of psychology and education, the Mendelian principle in heredity, and these the mathematician may study in terms of averages, index numbers, correlations, deviations, frequency distributions and otherwise. Just as the multiplication table is applicable in more than one field of knowledge, so mathematics in general is peculiar to none. Sooner or later every true science tends to become mathematical. The social sciences are simply a little later to be reached than astronomy, physics and chemistry, while the biological sciences are later still.

Scientific method is one and the same, whether employed in such sciences as Gibbs developed, or in others. Mathematics is, as Gibbs said, simply a "language." It is required for the best expression of scientific method when the relations to be expressed become sufficiently involved to require it in preference to ordinary language which is less precise and complete. The outlook is bright for a healthy development of mathematics in the social sciences.

LUNAR TEMPERATURES

By Dr. EDISON PETTIT and Dr. SETH B. NICHOLSON
CARNEGIE INSTITUTION OF WASHINGTON, MOUNT WILSON OBSERVATORY

OUR knowledge of the temperature of a celestial object must come through its radiation, which has suffered losses by filtration through its own and the earth's atmosphere and in the observing instruments. In the cases of the moon, the planet Mercury and to a great extent Mars, the first of these absorptions is negligible, and the problem of determining their surface temperatures is simpler than for the other planets.

The term radiation as used here means collectively ultra-violet, visual and infra-red light, the only distinguishing physical feature between these divisions being their wave-lengths. The unit of wave-length in common use is the micron (μ), which is one thousandth of a millimeter or ten thousand angstroms. Ultra-violet light consists of all wave-lengths less than $0.4\,\mu$; visual light, that between $0.4\,\mu$ and $0.76\,\mu$, and infra-red light, all wave-lengths greater than $0.76\,\mu$. The unit of intensity is one calory per square centimeter per minute, written 1 cal cm^{-2} min^{-1}.

The radiation from a planet consists of reflected solar radiation, which is practically confined to the wave-lengths between $0.3\,\mu$ and $5\,\mu$, and low temperature radiation from its warmed surface, called planetary heat, which reaches us principally through the great transmission band in the atmospheric water-vapor between 8 and $14\,\mu$. With the exception of cosmic radiation below the X-ray region no celestial radiation to the violet of wave-length $0.2897\,\mu$, or to the red of $15\,\mu$ has been detected, although the latter wave-length is still somewhat uncertain. The shaded curve in Fig. 1 shows the atmospheric transmission for radiation from a celestial object in the zenith on Mount Wilson. From this figure it can be seen that the reflected radiation between $0.3\,\mu$ and $5\,\mu$ is transmitted by a glass plate 0.165 mm thick (microscope cover-glass) while most of the planetary heat is not transmitted by it. Hence this thin glass becomes a means of separating the two kinds of radiation from a planet.

The general scheme which we have used for determining planetary temperatures consists in the following steps. (1) Measure with the vacuum thermocouple on an arbitrary scale the whole radiation (reflected light plus planetary heat) from a small area of the planet, and that transmitted by the cover-glass (practically all the reflected light and a nearly negligible amount of planetary heat). (2) Calibrate these measures by the radiation from a star which we have already standardized. (3) Separate the planetary heat from the reflected light by subtracting the radiation transmitted by the cover-glass from the total radiation received and apply small corrections necessary because of the slight absorption of reflected light and the slight transmission of planetary heat. (4) Compare the planetary heat so determined with that which computation shows would be obtained with our instruments from a black body at various temperatures outside our atmosphere.

In making the observations a vacuum thermocouple with a window made of rock salt is mounted at the focus of a reflecting telescope. The two junctions of the thermocouple, which are only two or three millimeters apart, are made by fusing two small wires of bismuth to the ends of another which is an alloy of 95 per cent. bismuth and 5 per cent. tin.

These are connected electrically to a D'Arsonval galvanometer in such a manner that the currents which are produced when the individual junctions are heated separately flow in opposite directions. When both junctions are heated simultaneously no deflection occurs, hence the thermocouple is compensated against general radiation from the sky and surrounding objects. In the case of the moon the image was so large that it would heat both junctions and it was necessary to shield all the thermocouple except one junction, hence the compensation was only partial, but since the required sensitivity was low this caused no inconvenience.

Small thin metal plates $\frac{1}{2}$ to 1 mm square are fused over the junctions of the thermocouple wires and covered with a mixture of lamp-black and platinum-black on their exposed surfaces. These black plates absorb within about 2 per cent. all the radiation from celestial objects and convert it into heat which, for the small changes of temperature obtained in practice, produces a thermoelectric current proportional to the intensity of the radiation received, irrespective of its wave-length. There is a current popular idea that thermocouples measure "radiant heat" or infra-red light, but radiation instruments such as the thermocouple, bolometer and radiometer when made with black receivers are perfectly color-blind and do not distinguish the various wave-lengths, measuring ultra-violet, visual and infra-red radiation with equal facility.

Of the radiation which is measured from the red variable star χ Cygni at minimum more than 99 per cent. is infra-red light; from the star Sirius 80 per cent. is visual and ultra-violet light, while from the sun 56 per cent. is visual and ultra-violet and 44 per cent. infra-red radiation. The radiation from the star Betelgeuse when focused on the receiver of a thermocouple by the 100-inch reflector raises its temperature fifteen thousandths of a degree, and the star Boss 4342, which is eight magnitudes fainter radiometrically, raises the temperature of the receiver only nine millionths of a degree Centigrade. These small temperature changes produce currents of the order of one and a half ten millionths of an ampere and 9×10^{-11} amperes, respectively.

The measurements could be calibrated in the fundamental way by comparing the observed deflections with those obtained from a standard radiator at a known distance. For example, the Hefner lamp at sea-level, without a diaphragm, emits 0.00156 calories per minute on each square centimeter (156×10^{-5} cal cm^{-2} min^{-1}) at a distance of one meter. This is an inconvenient process when the thermocouple is attached to the telescope, and so we have calibrated the radiation from certain stars and use them as standards.

To facilitate computation we have established a scale of magnitudes for stellar radiation called "radiometric magnitude" which agrees with the visual magnitude scale for the blue stars, type Ao. The radiometric magnitude of a star, therefore, is the visual magnitude of an Ao star which would give the same galvanometer deflection when both are observed with a reflecting telescope. From direct comparisons of stars with the sun, a Hefner lamp and a condensed filament electric light, we find that the energy which reaches us from a star of zero radiometric magnitude in the zenith on Mount Wilson is 17.3×10^{-13} cal cm^{-2} min^{-1}, and from this the energy which we receive from any star of known radiometric magnitude may be determined.

Table I is a list of stars in order of their radiometric magnitude (column 3) which have been used as standards. The last two columns of this table give the energy, E, which reaches the thermocouple, and E′, that which reaches the

solar system, expressed in both cases in cal $\times 10^{-12}$ cm^{-2} min^{-1}. The difference between these two columns is the energy absorbed in the earth's atmosphere and in the telescope.

TABLE I

Star	Sp. Type	Rad. Mag.	Vis. Mag.	E	E′
Betelgeuse	M2	−1.67	0.92	81	132
Antares	M1	−1.32	1.22	58	96
Sirius	A2	−1.27	−1.58	56	145
Arcturus	Ko	−0.98	0.24	43	64
Aldebaran	K5	−0.60	1.06	30	46
Capella	Go	−0.38	0.21	25	36
Vega	A1	0.10	0.14	16	44
Procyon	F3	0.22	0.48	14	22
Rigel	B8	0.23	0.34	14	50
Pollux	G9	0.53	1.21	11	20
α Ceti	M2	0.72	2.82	8.9	14
Altair	A2	0.74	0.89	8.8	23
Spica	B3	1.00	1.21	7.4	48
α Arietis	K1	1.24	2.23	5.5	8
Regulus	B9	1.47	1.34	4.5	14

The image of a star is always smaller than a receiver of the thermocouple, so that the deflections produced by it are independent of the size of the receiver, but when the moon or a planet is observed the deflections depend on the size of the receiver if it is smaller than the image of the observed object. It is, therefore, necessary to reduce the planetary observations to a receiver of definite size, and one square second of arc, in the telescope field, has been adopted for that standard.

The part of the total deflection which is due to planetary heat is determined by taking the difference between it and the deflection with the thin glass in the optical beam. The latter must be corrected for the losses by reflection from its two surfaces, the absorption of the glass and its transmission of a small amount of planetary heat. In the case of the moon these corrections amount to about 3 per cent. of the observed lunar radiation.

In computing the temperature corresponding to the observed planetary heat the assumption is made that the planet under observation radiates like a black body. In the case of the moon less than one eighth of the incident solar radiation is reflected, and this low reflecting power indicates an approach to the condition of a black body. The assumption is further justified by the observation that when a plate of fluorite is used as an absorbing screen the planetary heat absorbed by it has the same ratio to that transmitted as would be expected from a black body at that temperature.

The amount of energy radiated per unit of surface from a black body varies as the fourth power of its absolute temperature, and the amount of radiation of each wave-length is known for each temperature from Planck's formula. It is possible, therefore, to compute the amount of radiation which would reach our instruments from an area which subtends an angle of one square second of arc of a black body at various temperatures, making allowance for the losses in our atmosphere and in the telescope. The computed values of planetary heat for various temperatures are given in Table II. By entering this

TABLE II

T (K) Absolute	T (C) Centigrade	E	m'_r	$\Delta m'_r$
100°	−173°	0.00016	+12.47	−0.49
200	− 73	0.140	+ 5.28	−0.28
300	+ 27	1.36	+ 2.76	−0.20
400	+127	5.73	+ 1.45	−0.18
500	+227	10.0	+ 0.60	−0.18
600	+327	17.5	− 0.01	−0.17
700	+427	26.4	− 0.46	−0.17
800	+527	37.8	− 0.85	−0.16

table with the quantity of radiation observed for any point on the moon or planet its temperature may be obtained. Here T (K) is the absolute temperature of the planetary surface in degrees.

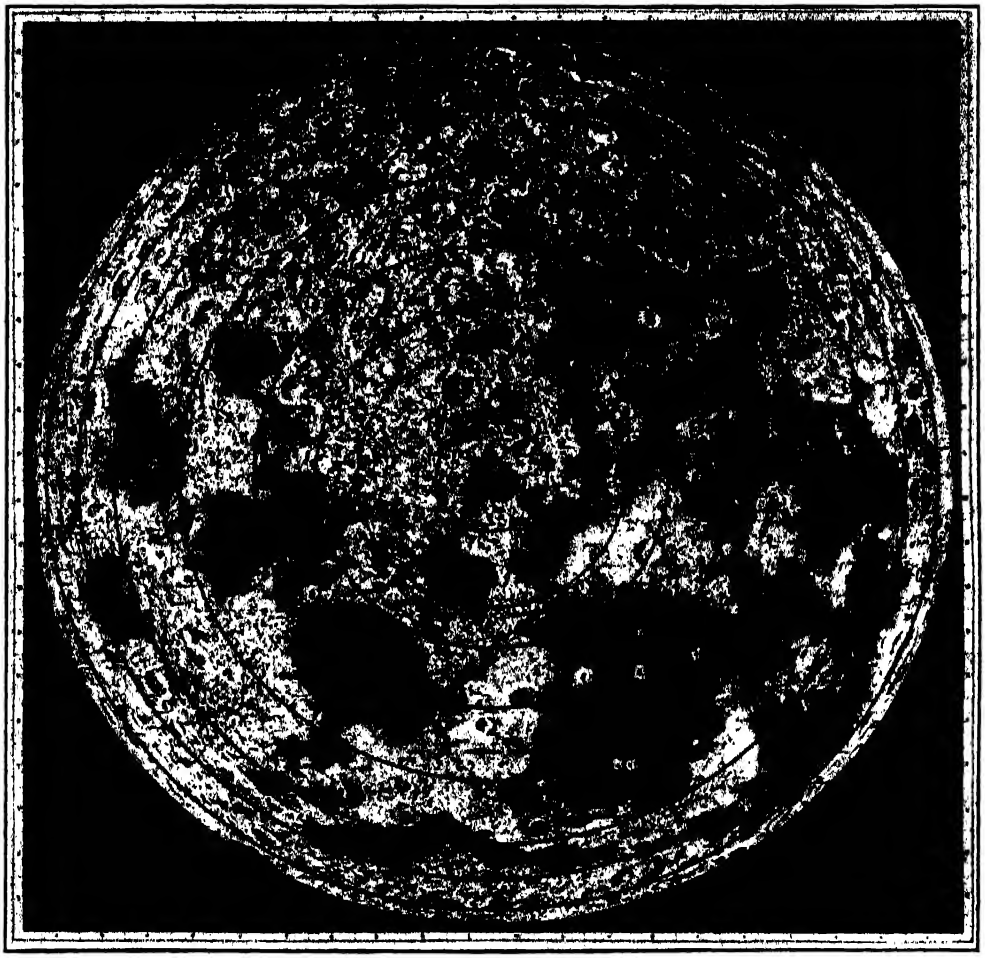


PLATE I. ISOTHERMAL LINES ON THE MOON

Centigrade; T (C) is the corresponding temperature Centigrade; E is the planetary heat eliminated by the microscope cover-glass, in a solid angle of one square second of arc, expressed in units of 10^{-12} calories per square centimeter per minute; m'_r is the radiometric magnitude corresponding to this energy, and $\Delta m'_r$ is a small correction obtained from the theoretical lunar temperature as described later.

From observations extending over a period since 1923 we find that the temperature deduced for the point on the moon where the sun is directly overhead is 135° C. when measured at full moon, but only 82° C. when measured at quarter phase. The difference in these results is evidently due to the fact that the rough surface increases the radiation toward the lunar zenith but diminishes that toward the horizon, and the actual temperature from the radiation measurements lies between these figures.

To determine the actual temperature the distribution of planetary heat and light about the subsolar point was determined by measurements made from night to night as the subsolar point passed over the earthward face of the

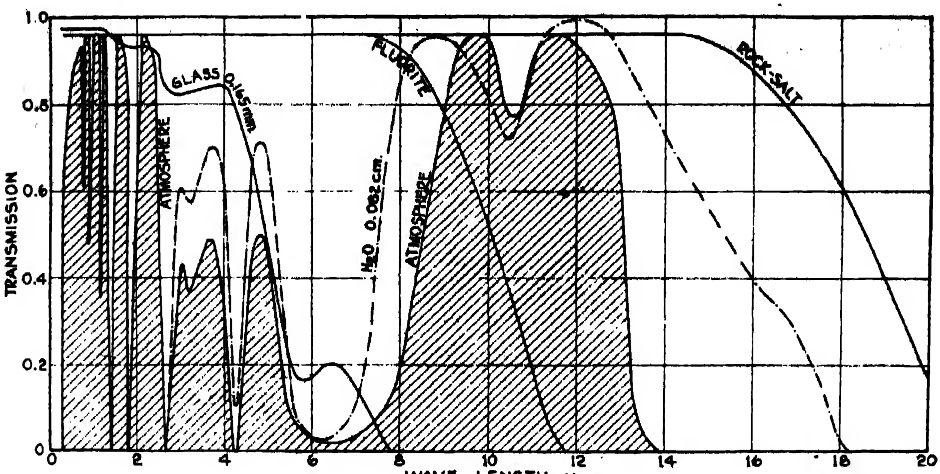


FIG. 1. TRANSMISSION CURVES.

moon between first and last quarter. The curves for both light and planetary heat are given in Fig. 2. The mean radiation in all directions from the sub-solar point was 1.93 cal cm^{-2} min^{-1}, which is equivalent to a temperature of 118° C.

The temperature of the subsolar point may be computed from the solar constant (1.95 cal cm^{-2} min^{-1}) after deducting the solar radiation reflected by the surface of the moon and that conducted into its interior. From the distribution of reflected light shown in Fig. 2 we find that 0.24 cal cm^{-2} min^{-1} is reflected into space, and from measurements of the rate of cooling during an eclipse of the moon we find that less than 0.1 cal cm^{-2} min^{-1} is conducted into the moon, showing that it is a very poor conductor. Therefore the solar radiation effective in warming the lunar surface and that which must be radiated from it is 1.61 cal cm^{-2} min^{-1}, which is equivalent to a temperature of 101° C. The tempera- therefore, 17° C. in excess of that theo- ture obtained from direct measures is, retically possible from a consideration of the quantity of solar radiation available to heat the moon.

Of the various explanations of this discrepancy which have been considered, an error in the values of the atmospheric transmissions seems to be the most probable, owing to the difficulty of determining the transmission constants of the atmosphere for radiation with wave-lengths between 8 and 14 microns. An increase of 19 per cent. in the atmospheric transmissions used in reducing the direct measures would decrease the resulting temperature 17° C., and accordingly we have computed corrections to the atmospheric absorption for various temperatures based on that assumption. These corrections are given in Table II as $\Delta m'_r$. When these corrections are used in obtaining temperatures of other planets or other regions on the moon the results may be considered as having been obtained by a comparison of the measured radiation with that from the subsolar point on the moon, assigning to it the temperature deduced from the amount of incident solar radiation corrected for losses which have been determined by direct observation with the thermocouple. The effect of these corrections is to lower the measured temperatures of Mercury about 45° C., Venus 9°, Mars 10° and the moon 17°.

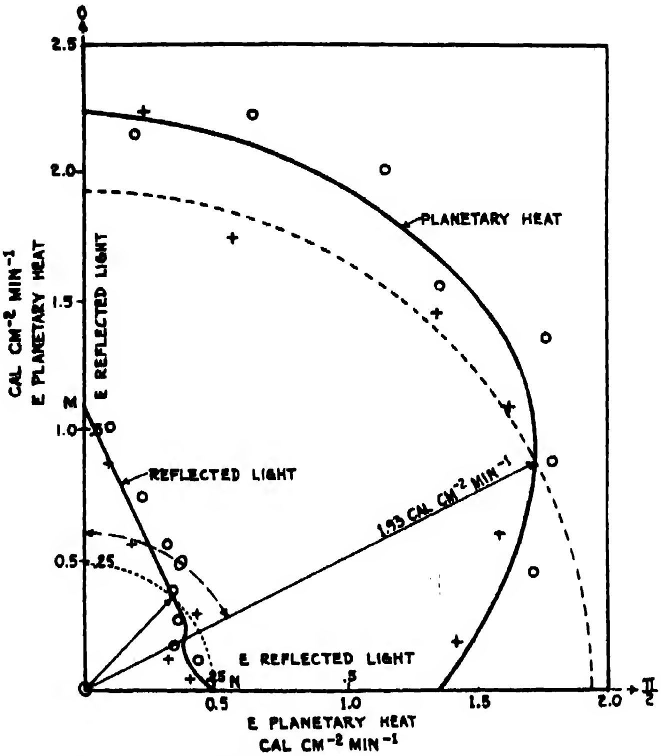


FIG. 2. DISTRIBUTION OF PLANETARY HEAT

AND REFLECTED SUNLIGHT ABOUT THE SUBSOLAR POINT ON THE MOON.

Measurements made on the dark side of the moon gave $-153°$ C. for its temperature. This is so low that considerable observing will be necessary to determine it accurately, for the lower limit of temperature which we can detect is a little less than $-173°$ C.

The variation of radiation and temperature over the sunlit side of the moon was obtained by allowing the image of the full moon to transit the thermocouple while a moving photographic plate traced the resulting galvanometer deflections called drift curves. Drift curves in a north and south direction were obtained by driving the thermocouple with a motor. The planetary heat was found to vary from a practically unmeasurable quantity at the limb to a maximum value at the center approximately as cosine$^{3/2}$ θ, where θ is the angular distance on the moon from the subsolar point. Plate I is a plot of the isothermal lines, upon a relief map of the moon, in degrees Centigrade computed from this data. They represent mean values and do not distinguish between the light and dark areas. The maria are, in general, somewhat warmer than the mountainous regions, but the difference is only a few degrees.

The diurnal march of temperature for a point near the equator on the moon determined from the above data is shown by the line labeled "Moon, Equator" in Fig. 3. From this and what has been said above it is seen that

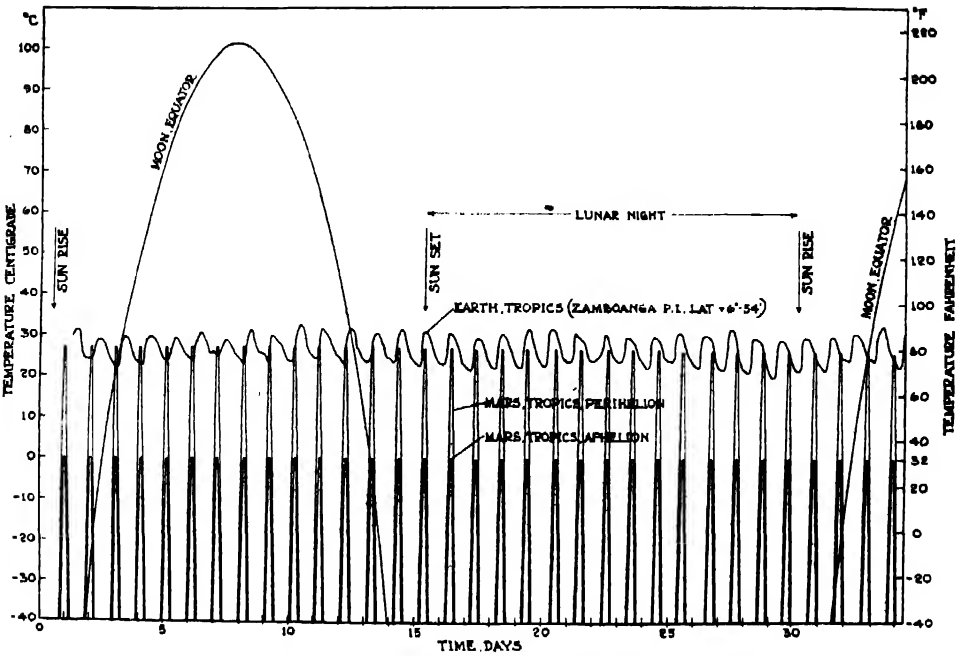


FIG. 3. DIURNAL VARIATION IN TEMPERATURE ON THE EARTH, MOON AND MARS COMPARED.

the temperature rises from that of liquid air at sunrise to the boiling-point of water at lunar noon, returns as the sun becomes lower in the lunar sky and hovers near that of liquid air during the next fortnight. The line labeled "Earth, Tropics" is the diurnal variation in temperature for a point near the earth's equator, Zamboanga, Philippine Islands (lat. 6° 54′ N). The contrast in temperature range is very striking. The graph for Mars was obtained from drift curves on the planet which we took at the oppositions of 1924 and 1926, and they were reduced in the same manner as those for the moon described here. The curve shows that the maximum temperature comes near noon and that the fall in temperature is very large as the sun approaches the Martian horizon, indicating a very dry atmosphere. An interesting feature of this curve is the large range of 27° C. in the noon temperature between perihelion and aphelion calculated from the eccentricity of the planet's orbit. In the case of the earth this effect would amount to only one degree and would be masked by other climatic variables.

The changes in temperature which take place during a lunar eclipse were investigated at the eclipse of June 14, 1927. A point near the south limb of the moon was chosen for continuous measurement since this point passed only 11′ north of the center of the umbra of the earth's shadow. For this point the duration of the eclipse was $2^h\ 40^m$, the partial phases being 1^h each. The temperature T, the energy E_R received from the sun and E emitted by the moon during the eclipse are shown diagrammatically in Fig. 4. For the point measured, the temperature fell from 342° K = 69° C. to 175° K = −98° C. during the first partial phase, continued to drop to 156° K = −117° C. during totality and rose again abruptly

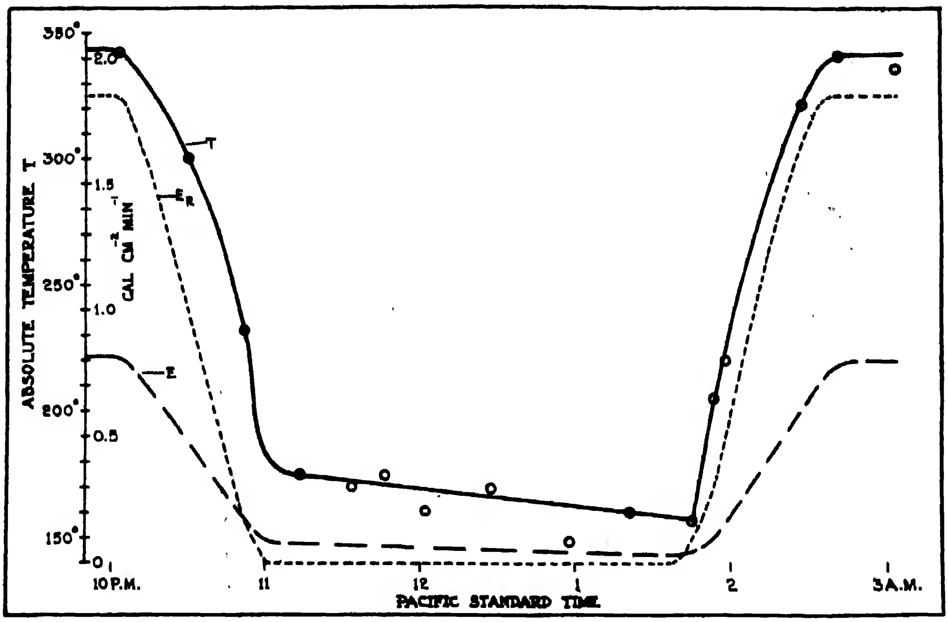


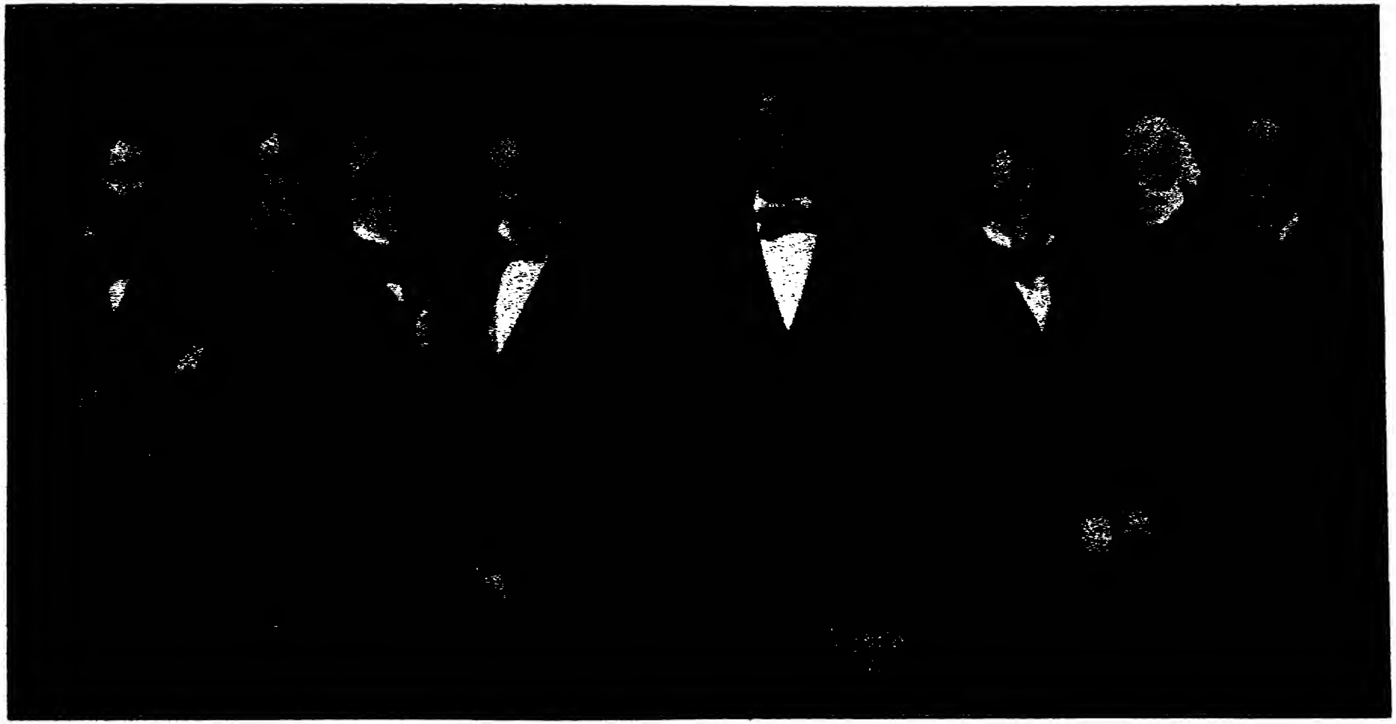
FIG. 4. LUNAR TEMPERATURE

ENERGY RECEIVED AND ENERGY EMITTED BY THE MOON DURING A LUNAR ECLIPSE.

to nearly the original temperature during the last partial phase. The deflections even toward the end of totality were between 2 and 3 mm and could be measured with precision by the methods which we used.

From this curve it can be shown that the heat conductivity of the lunar crust is very low, probably on account of its porous or granular nature, and only about 0.1 cal cm^{-2} min^{-1} (5 per cent.) of the energy received at the subsolar point is transmitted into the interior of the moon.

The enormous change in temperature of 186° C. observed in this lunar eclipse, the greater part of which took place during the partial phase, is in strong contrast to the fall of 2.8° C. observed at the solar eclipse of June 8, 1918, by the Washburn College party at Matheson, Colorado, where the duration of the partial phase was nearly the same. This serves to illustrate the governing effect of an atmosphere on planetary temperatures, since in this illustration the only physical distinction between the two circumstances was the presence of an atmosphere at the solar eclipse observed from the earth. It is chiefly the presence of water-vapor as a constituent of the earth's atmosphere which gives it this property, and the large diurnal variation in the temperature of Mars shown in Fig. 3 indicates a lack of this constituent in its atmosphere.



FOUNDERS OF THE NATIONAL ACADEMY OF SCIENCES

A photograph of the painting by Albert Herter in the board room of the Academy building. The names, reading from left to right, are: Benjamin Peirce, Alexander Dallas Bache, Joseph Henry, Louis Agassiz, Abraham Lincoln, Senator Henry Wilson, Admiral Charles H. Davis, Benjamin Apthorp Gould. The picture was planned by Dr. George Ellery Hale. It is a group of men who were in Washington about the year 1863 and who consulted among themselves regarding the formation of an academy to advise the government in scientific matters. The bill in Congress was sponsored by Senator Wilson.

THE PROGRESS OF SCIENCE

THE SPRING MEETING OF THE NATIONAL ACADEMY OF SCIENCES

THE National Academy held its annual meeting in Washington during the last week in April; at the same time there met in the national capital many other societies, groups and committees concerned with scientific work. The charter of the academy, approved by Abraham Lincoln on March 3, 1863, when the country was in the midst of civil war, requires the academy to "investigate, examine, experiment and report upon any subject of science or art," whenever called upon by any department of the government. This duty of the academy has in large measure been taken over by the scientific bureaus of the government since organized, but when war became imminent in 1916 there was established at the request of Woodrow Wilson the National Research Council under the Congressional charter of the National Academy. After performing useful services during the war the council was continued as an agency of the academy. The academy and the council occupy jointly a beautiful marble building near the Lincoln Memorial, completed six years ago at a cost of one and a half million dollars as the last work of the distinguished architect, Bertram Grosvenor Goodhue.

When the National Academy was chartered the number of members was limited to fifty, but this restriction was removed by the Congress in 1870. According to its present rules fifteen new members may be elected each year, the total membership having been limited to 250 until this year when the upper limit was made 300. The Royal Society elects

THE BUILDING OF THE NATIONAL ACADEMY OF SCIENCES AND THE NATIONAL RESEARCH COUNCIL

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fifteen members and maintains a membership of about 400. The National Academy is thus smaller than the Royal Society but larger than the Paris Academy and other continental academies. As there are now some 20,000 men engaged in scientific work in the United States the selection of fifteen of these is a high distinction. Photographs are presented of those elected with the exception of Dr. J. W. Alexander, professor of mathematics, Princeton University, and Dr. Eugene T. Allen, research chemist, Geophysical Laboratory, Carnegie Institution of Washington.

The distribution of the members of the academy among the different states and institutions gives a measure of interest in research and appreciation of the work of leaders in science. It will be noted that of the fifteen new members three are connected with the California Institute of Technology at Pasadena. There were already at the institute six members, including Dr. T. H. Morgan, the president of the academy, and Dr. R. A. Millikan, the foreign secretary. The Mount Wilson Observatory of the Carnegie Institution at Pasadena has no fewer than seven members, so there are fifteen members in these two institutions which did not exist a few years ago. Both are due to Dr. George Ellery Hale and represent a most remarkable achievement in the organization and advancement of scientific research. The University of California, with the Lick Observatory, has on its faculty fourteen members of the academy, and there are nine members at Stanford. California, until recently lacking in scientific men of high distinction, now ranks with Massachusetts and New York and is far in advance of any other state. There are only five members in Pennsylvania and two in Ohio.

There are thirty-eight members of the academy connected with Harvard University, and its retention of scientific leadership is as remarkable as the de-

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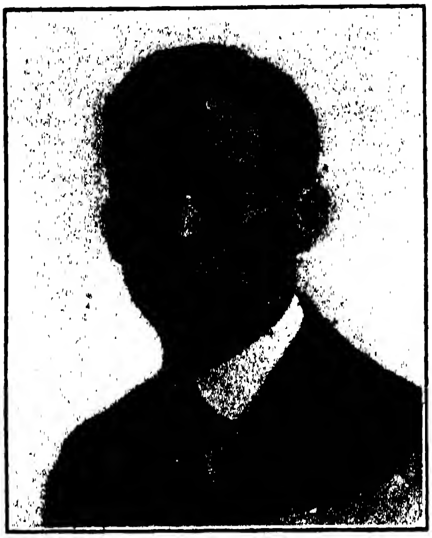

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velopment in California. An examination of the distribution among the different departments shows that in every science Harvard stands first or nearly first. There are seventeen members of the academy at Chicago, sixteen at Yale, thirteen at the Johns Hopkins, twelve at Columbia and ten at Princeton. Among the state universities Wisconsin

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has eight and Illinois five. There are distinguished scientific men in the government institutions and surveys at Washington, but relatively fewer than formerly. A recent notable development has been, on the one hand, the establishment of research institutions, particularly the Carnegie Institution of Washington and the Rockefeller Institute for Medical Research, and, on the other hand, the carrying out of research work in industrial laboratories, more especially by the General Electric Company and the American Telephone and Telegraph Company.

SIR WILLIAM BRAGG

THE AWARD OF THE FRANKLIN MEDAL TO SIR WILLIAM BRAGG AND DR. JOHN F. STEVENS

In 1913 Mr. Samuel Insull, of Chicago, gave to the Franklin Institute a certain sum for the founding of the Franklin Medal to be awarded from time to time in recognition of the total contributions of individuals to science or to the applications of physical science to industry. The medal is of gold, having on one side a medallion of Benjamin Franklin done from the Thomas Sully portrait, the original of which is in the possession of the institute.

This year two medals were awarded—one to Dr. John F. Stevens in recognition of his unifying solutions of widely varying and difficult engineering problems met in the planning of the great Panama Canal, of the marked power shown by him in the organization of the engineering forces which later built that canal and of his eminent success in the location, construction and administration of railroads in this country and in foreign lands; the other to Sir William Bragg in recognition of a life work in the study of X-rays and radioactivity in the course of which he made fundamental contributions to that realm of

DR. JOHN F. STEVENS

physics, of his development of a method of determining molecular and crystal structure by the reflection of X-rays and of his fruitful guidance of the Davy-Faraday Research Laboratory and of the Royal Institution of Great Britain.

Dr. Stevens was born at West Gardiner, Maine, in 1853. His first engineering experience was with a firm of engineers in Lewiston, but he was soon drawn to the West. From 1874 to almost the present time he has been associated with many American railroads, among which may be mentioned the Denver and Rio Grande; the Chicago, Milwaukee and St. Paul; the Canadian Pacific; the Great Northern, and the New York, New Haven and Hartford. His list of honors from governments is a long one, including the Distinguished Service Medal of the United States. He is an officer of the Legion of Honor of France. In 1925 he was awarded the John Fritz Medal, the highest honor American engineers can pay to one of their number.

A few of his splendid achievements are as follows. Early in 1889 he entered the service of the Great Northern Railway and was assigned the task of locating its line over the Rocky Mountains. This he did when he discovered the

Marios Pass, which has the lowest grades in the northern United States and is the straightest route from the head waters of the Mississippi to Portland and Puget Sound.

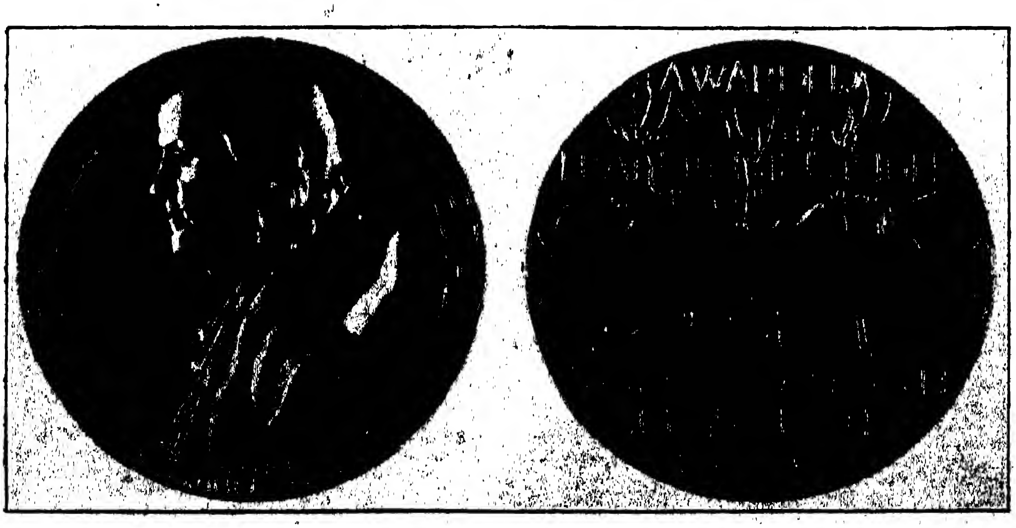
In 1905 Dr. Stevens was called by our government to take charge of the work of constructing the Panama Canal. He spent eighteen months in the Canal Zone as chief engineer; he brought order out of chaos, planned all the details of construction and organization and started the vast machine going with a contented and healthy army of 30,000 men.

Sir William Bragg was born at Wigton, England, in 1862. His collegiate education was obtained at Trinity College, Cambridge. In 1886 he was appointed professor of mathematics and physics in the University of Adelaide, Australia, and while there began his investigations in the field of radioactivity. In 1909 he was appointed Cavendish professor at Leeds University. In 1915 he became Quain professor of physics at the University of London, where he remained until his election in 1923 to his present position as director of the Royal Institution of Great Britain, Fullerian professor of chemistry at the Royal Institution and director of the Davy-Faraday Research Laboratory. He is a fellow and a Rumford medalist of the Royal Society. In 1915 he received the Nobel Prize for physics, which distinction he shared with his son, Professor W. Lawrence Bragg.

Sir William's extensive and valuable studies have been in the modern and important fields of radioactivity, X-rays and crystal structure, in fact, they are of such a fundamental nature that his name is a household word to all students in the exact sciences.

In radioactivity his experiments on the determination of the ranges of the alpha particles from various radioactive substances threw much light on the mechanics of ionization in gases and on the laws of absorption of these rays by matter.

In the field of X-rays and crystal structure he showed that the cleavage faces of a crystal reflect X-rays according to the same laws that apply in ordinary optical reflection, and he derived the formula known as the Bragg equation for space lattices. Using this equation and with observations made on numerous crystals by means of an X-ray spectrometer of his own design he determined the various distances between the atomic planes in these crystals and the nature of the atoms in these planes. In this way he put crystallography on an exact and measurable foundation.



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